## PCT

# WORLD INTELLECTUAL PROPERTY ORGANIZATION International Bureau



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	3 November 1 November 1997 (05 December 1997 (05.  d States except AT arzwaldallee 215, 0  VARTIS-ERFIND CHAFT MBH [AT	.11.97) 12.97) US): N CH-405	3.11.9 G U IOVAI 58 Bas	Takarazuka, Hyogo 665 (JP).  2–8–2, Sengen, Tsukuba–shi, [JP/JP]; Apartment 1, 401 Kita–ku, Kobe, Hyogo (JP). [US/US]; 11 Chippewa Trail, I GREENSPAN, Paul, David [US] Providence, NJ 07974 (US).  [GB/US]; 17 Crown Drive, TOMMASI, Ruben, Alberto [US] Whitehouse Station, NJ 08889 Henry [US/US]; 304 County R (US).  [74) Agent: BECKER, Konrad; Novart	TAKAI, Michihiro [JP/JP]; Ibaraki (JP). TENO, Naoki, Fujiwaradai—minamimati, COWEN, Scott, Douglas Branchburg, NJ 08876 (US). S/US]; 63 Ridge Drive, New MCQUIRE, Leslie, Wighton Warren, NJ 07059 (US). US/US]; 1 Plantation Road, (US). VAN DUZER, John, oad 579, Asbury, NJ 08802 is AG, Patent— und Marken-
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(54) Title: DIPEPTIDE NITRI ES

$$R = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \times \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \times \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \times \begin{bmatrix} 1 \\ 1 \end{bmatrix} \times \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \times \begin{bmatrix} 1 \\ 1 \end{bmatrix} \times$$

#### (57) Abstract

N-terminal substituted dip ptide nitriles as defined are useful as inhibitors of cysteine cathepsins, e.g. cathepsins B, K, L and S, and can be used for the treatment of cyste ne cathepsin dependent diseases and conditions, including inflammation, rheumatoid arthritis, osteoarthritis, osteoporosis, tumors (especially tumor invasion and tumor metastasis), coronary disease, atherosclerosis (including atherosclerotic plaque rupture and destabilization). Par icular dipeptide nitriles are compounds of formula (I), or physiologically-acceptable and —cleavable esters or salts thereof, wherein: the sy nbols are as defined. In particular it has been found that by appropriate choice of groups R, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, X<sub>1</sub>, Y and L, the relative selectivity of the compounds as inhibitors of the various cysteine cathepsin types, e.g. cathepsins B, K, L and S, may be altered, e.g. to obtain inhibitors which selectively inhibit a particular cathepsin type or combination of cathepsin types.

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for use as a pharmaceutical.

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## **CLAIMS**

- 1. A dipeptide nitrile in which the C-terminal carboxy group of the dipeptide is replaced by a nitrile group (-C≡N) and in which the N-terminal nitrogen atom is substituted via a peptide or pseudopeptide linkage which optionally additionally comprises a -methylene-hetero atom-linker or an additional hetero atom, directly by aryl, lower alkyl, lower alkenyl, lower alkynyl or heterocyclyl, or a physiologically-acceptable and -cleavable ester or a salt thereof,
- 2. A compound of formula I, or a physiologically-acceptable and -cleavable ester or a salt thereof

$$R = \begin{bmatrix} L \\ X_1 - NH \end{bmatrix} \begin{bmatrix} R_3 \\ R_2 \end{bmatrix} \begin{bmatrix} R_4 \\ R_5 \end{bmatrix} C = \begin{bmatrix} N \\ R_5 \end{bmatrix}$$

wherein:

R is optionally substituted (aryl, lower alkyl, lower alkenyl, lower alkynyl, or heterocyclyl); R<sub>2</sub> and R<sub>3</sub> are independently hydrogen, or optionally substitued [lower alkyl, cycloalkyl, bicycloalkyl, or (aryl, biaryl, cycloalkyl or bicycloalkyl)-lower alkyl]; or R<sub>2</sub> and R<sub>3</sub> toge her represent lower alkylene, optionally interrupted by O, S or NR<sub>6</sub>, so as to form a ring with the carbon atom to which they are attached

wherein  $R_6$  is hydrogen, lower alkyl or aryl-lower alkyl; or either  $R_2$  or  $R_3$  are linked by lower alkylene to the adjacent nitrogen to form a ring;  $R_4$  and  $R_5$  are independently H, or optionally substituted (lower alkyl, aryl-lower alkyl), -  $C(O)OR_7$ , or  $-C(O)NR_7R_8$ ,

wherein

R<sub>7</sub> is optionally substituted (lower alkyl, aryl, aryl-lower alkyl, cycloalkyl, bicycloalkyl or heterocy:lyl), and

R<sub>8</sub> is H, or optionally substituted (lower alkyl, aryl, aryl-lower alkyl, cycloalkyl, bicycloalkyl or heterocyclyl), or

R<sub>4</sub> and R<sub>5</sub> together represent lower alkylene, optionally interrupted by O, S or NR<sub>6</sub>, so as to form a ring with the carbon atom to which they are attached

wherein R<sub>6</sub> is hydrogen, lower alkyl or aryl-lower alkyl, or

 $R_4$  is H or optionally substituted lower alkyl and  $R_5$  is a substituent of formula  $-X_2-(Y_1)_n-(Ar)_p$ -Q-Z

wherein

Y<sub>1</sub> is O, S, SO, SO<sub>2</sub>, N(R<sub>6</sub>)SO<sub>2</sub>, N-R<sub>6</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub> or NR<sub>6</sub>CO;

n is zero or one;

p is zero or one;

X<sub>2</sub> is lower alkylene; or when n is zero, X<sub>2</sub> is also C<sub>2</sub>-C<sub>7</sub>-alkylene interrupted by O, S, SO, SO<sub>2</sub>, NR<sub>6</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub> or NR<sub>6</sub>CO;

wherein R<sub>6</sub> is hydrogen, lower alkyl or aryl-lower alkyl;

Ar is arylene;

Z is hydroxy, acyloxy, carboxyl, esterified carboxyl, amidated carboxyl, aminosulfonyl, (lower alkyl or aryl-lower alkyl)aminosulfonyl, or (lower alkyl or aryl-lower alkyl)sulfonylaminocarbonyl; or Z is tetrazolyl, triazolyl or imidazolyl;

Q is a direct bond, lower alkylene, Y<sub>1</sub>-lower alkylene or C<sub>2</sub>-C<sub>7</sub>-alkylene interrupted by Y<sub>1</sub>;

 $X_1$  is -C(O)-, -C(S)-, -S(O)-, -S(O)<sub>2</sub>-, or -P(O)(OR<sub>6</sub>)-,

wherein R<sub>6</sub> is as defined above;

Y is oxygen or sulphur;

L is optionally substituted -Het-, -Het-CH<sub>2</sub>- or -CH<sub>2</sub>-Het-,

wherein Het is a hetero atom selected from O, N or S, and

x is zero or one;

and aryl in the above definitions represents carbocyclic or heterocyclic aryl,

for use as a pharmaceutical;

a pharmaceutical composition comprising a compound of formula I as defined above as an active ingredient;

a method of treating a patient suffering from or susceptible to a disease or medical condition in which a cathepsin is implicated, comprising administering an effective amount of a compound of formula I as defined above to the patient; or

use of a compound of formula I as defined above for the preparation of a medicament for therapeutic or prophylactic treatment of a disease or medical condition in which a cathepsin is implicated.

3. A compound of formula I as defined in claim 2,

provided that when R is lower alkyl not substituted by aryl,

one of  $R_4$  or  $R_5$  is a substituent of formula  $-X_2-(Y_1)_n-(Ar)_p-Q-Z$ ;

provided that when x is one, L is -O-, or -CH<sub>2</sub>-O- and  $X_1$  is -C(O)-,

either one of  $R_4$  or  $R_5$  is a substituent of formula  $-X_2$ - $(Y_1)_n$ - $(Ar)_p$ -Q-Z, or R is not unsubstituted phenyl;

provided that when  $R_2 = R_4 = R_5 = H$ , x is zero and  $X_1$  is -C(O)-,

R<sub>3</sub> is not H, -CH<sub>3</sub>, -CH(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-COOH, or -CH<sub>2</sub>-COO-CH<sub>2</sub>-CH<sub>3</sub>, when R is unsubstituted phenyl,

R<sub>3</sub> is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when R is 4-aminophenyl or 4-nitrophenyl,

R<sub>3</sub> is not H when R is 3-aminophenyl, 3-nitrophenyl 2-chloropyridin-4-yl, or vinyl or

R<sub>3</sub> is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when R is pyridin-3-yl or 2-chloropyridin-4-yl,

provided that when  $R_2 = R_3 = R_4 = H$ , x is zero and  $X_1$  is -C(O)- and R is phenyl,

 $R_5$  is not -CH(CH<sub>3</sub>)<sub>2</sub>,

provided that when  $R_3 = R_4 = H$ ,  $R_5$  is -CH<sub>2</sub>-CH<sub>2</sub>-COOH, x is zero and  $X_1$  is -C(0)-,

 $R_2$  does not form a heterocyclic ring with the adjacent nitrogen atom, and provided that when  $R_2 = R_3 = R_4 = R_5 = H$ , x is zero and  $X_1$  is  $-SO_2$ -,

R is not 4-methylphenyl.

4. A compound according to claim 3, of formula II, or a physiologically-acceptable and -cleavable ester or a salt thereof

$$R_{20} = L' - X_1 - NH + R_{23} - N - R_{24} - C = N$$

$$X_1 - NH + R_{22} - N - R_{25} - R_{$$

wherein:

•

R<sub>20</sub> is optionally substituted (aryl, aryl-lower alkyl, lower alkenyl, lower alkynyl, heterocyclyl, or heterocyclyl-lower alkyl);

R<sub>22</sub> is H, or optionally substitued lower alkyl, and

R<sub>23</sub> is optionally substituted (lower alkyl, aryl-lower alkyl, or cyloalkyl-lower alkyl) or

R<sub>22</sub> and R<sub>23</sub> together with the carbon atom to which they are attached form an optionally substituted (cycloalkyl group or heterocycloalkyl group);

 $R_{24}$  and  $R_{25}$  are independently H, or optionally substituted (lower alkyl, or aryl-lower alkyl), -  $C(O)OR_7$ , or - $C(O)NR_7R_8$ ,

wherein R<sub>7</sub> and R<sub>8</sub> are as defined above, or

R<sub>24</sub> and R<sub>25</sub> together with the carbon atom to which they are attached form an optionally substituted (cycloalkyl group or heterocycloalkyl group);

 $X_1$  is as defined in claim 2;

Y is oxygen or sulphur;

L' is optionally substituted (-Het-CH<sub>2</sub>- or -CH<sub>2</sub>-Het-),

wherein Het is a a hetero atom selected from O, N or S, and

x is 1 or 0,

provided that when x is one,  $\coprod$  is -CH<sub>2</sub>-O- and X<sub>1</sub> is -C(O)-,

R<sub>20</sub> is not unsubstituted phenyl,

provided that when  $R_{22} = R_{24} = R_{25} = H$ , x is zero and  $X_1$  is -C(O)-,

R<sub>23</sub> is not H, -CH<sub>3</sub>, -CH<sub>2</sub>(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-COOH, or -CH<sub>2</sub>-COO-CH<sub>2</sub>-CH<sub>3</sub>, when R<sub>20</sub> is unsubstituted phenyl,

R<sub>23</sub> is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when R<sub>20</sub> is 4-aminophenyl or 4-nitrophenyl,

 $R_{23}$  is not H when  $R_{20}$  is 3-aminophenyl, 3-nitrophenyl 2-chloropyridin-4-yl, or vinyl, or  $R_{23}$  is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when  $R_{20}$  is pyridin-3-yl or 2-chloropyridin-4-yl,

provided that when  $R_{22} = R_{23} = R_{24} = H$ , x is zero and  $X_1$  is -C(O)- and  $R_{20}$  is phenyl,

 $R_{25}$  is not -CH(CH<sub>3</sub>)<sub>2</sub>,

provided that when  $R_{23} = R_{24} = H$ ,  $R_{25}$  is -CH<sub>2</sub>-COOH, x is zero and  $X_1$  is -C(O)-,

 $R_{22}$  does not form a heterocyclic ring with the adjacent nitrogen atom, and provided that when  $R_{22} = R_{23} = R_{24} = R_{25} = H$ , x is zero and  $X_1$  is -SO<sub>2</sub>-,

R<sub>20</sub> is not 4-methylphenyl.

5. A compound according to claim 3, of formula II' or a physiologically-acceptable and - cleavable ester or a salt thereof

$$R_{20} = L' - X_1 - NH + C - N - R_{24}' - C = N$$

$$X = NH + C - N - R_{25} - R_{25$$

wherein:

 $R_{20}$ ' is optionally substituted ( $C_6$ - $C_{18}$  aryl or  $C_4$ - $C_{18}$  heteroaryl);

R<sub>22</sub>' is H, or optionally substitued C<sub>1</sub>-C<sub>8</sub> alkyl, and

 $R_{23}$ ' is optionally substituted ( $C_2$ - $C_8$  alkyl, or  $C_7$ - $C_{14}$  aralkyl), or

R<sub>22</sub>' and R<sub>23</sub>' together with the carbon atom to which they are attached form an optionally substituted (C<sub>3</sub>-C<sub>8</sub> cycloalkyl group or C<sub>4</sub>-C<sub>7</sub> heterocycloalkyl group);

 $R_{24}$ ' and  $R_{25}$ ' are independently H, or optionally substituted (C<sub>1</sub>-C<sub>8</sub> alkyl, C<sub>7</sub>-C<sub>14</sub> aralkyl, or C<sub>5</sub>-C<sub>14</sub> heteroaralkyl), -C(O)OR<sub>6</sub>', or -C(O)NR<sub>6</sub>'R<sub>7</sub>',

wherein

 $R_6$ ' is optionally substituted ( $C_1$ - $C_8$  alkyl,  $C_7$ - $C_{14}$  aralkyl,  $C_3$ - $C_8$  cycloalkyl,  $C_4$ - $C_7$  heterocycloalkyl,  $C_5$ - $C_{14}$  heteroaralkyl,  $C_6$ - $C_{14}$  aryl, or  $C_4$ - $C_{14}$  heteroaryl), and  $R_7$ ' is H, or optionally substituted ( $C_1$ - $C_8$  alkyl,  $C_7$ - $C_{14}$  aralkyl,  $C_3$ - $C_8$  cycloalkyl,  $C_4$ - $C_7$  heterocycloalkyl,  $C_5$ - $C_{14}$  heteroaralkyl,  $C_6$ - $C_{14}$  aryl, or  $C_4$ - $C_{14}$  heteroaryl), or

R<sub>24</sub>' and R<sub>25</sub>' together with the carbon atom to which they are attached form an optionally substituted (C<sub>3</sub>-C<sub>8</sub> cycloalkyl group or C<sub>4</sub>-C<sub>7</sub> heterocycloalkyl group);

$$X_1$$
 is -C(O)-, -C(S)-, -S(O)-, -S(O)<sub>2</sub>-, -P(O)(OR<sub>6</sub>')-

wherein R<sub>6</sub>' is as defined above;

Y is oxygen or sulphur;

L' is optionally substituted (-Het-CH<sub>2</sub>- or -CH<sub>2</sub>-Het-),

wherein Het is a a hetero atom selected from O, N or S, and x is 1 or 0,

provided that when x is one, L' is  $-CH_2-O$  and  $X_1$  is -C(O)-

R<sub>20</sub>' is not unsubstituted phenyl,

provided that when  $R_{22}' = R_{24}' = R_{25}' = H$ , x is zero and  $X_1$  is -C(O)-,

R<sub>23</sub>' is not H, -CH<sub>3</sub>, -CH<sub>2</sub>(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-COOH, or -CH<sub>2</sub>-COO-CH<sub>2</sub>-CH<sub>3</sub>, when R<sub>20</sub>' is unsubstituted phenyl,

R<sub>23</sub>' is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when R<sub>20</sub>' is 4-aminophenyl or 4-nitrophenyl,

R<sub>23</sub>' is not H when R<sub>20</sub>' is 3-aminophenyl, 3-nitrophenyl, 2-chloropyridin-4-yl, or vinyl, or

 $R_{23}$ ' is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when  $R_{20}$ ' is pyridin-3-yl or 2-chloropyridin-4-yl, provided that when  $R_{22}$ ' =  $R_{23}$ ' =  $R_{24}$ ' = H, x is zero and  $X_1$  is -C(O)- and  $R_{20}$ ' is phenyl,

provided that when  $R_{23}' = R_{24}' = H$ ,  $R_{25}'$  is -CH<sub>2</sub>-CH<sub>2</sub>-COOH, x is zero and  $X_1$  is -C(O)-,

 $R_{20}$ ' does not form a heterocyclic ring with the adjacent nitrogen atom, and provided that when  $R_{22}$ ' =  $R_{23}$ ' =  $R_{24}$ ' =  $R_{25}$ ' H, x is zero and  $X_1$  is -SO<sub>2</sub>-,

R<sub>20</sub>' is not 4-methylphenyl.

 $R_{25}$ ' is not -CH(CH<sub>3</sub>)<sub>2</sub>,

# 6. A compound of formula III

wherein

 $R_{30}$  is an acyl group derived from an organic carboxylic, carbonic, carbamic or sulfonic acid;  $R_{32}$  and  $R_{33}$  are independently hydrogen, lower alkyl, cycloalkyl, bicycloalkyl, or (aryl, biaryl, cycloalkyl or bicycloalkyl)-lower alkyl; or  $R_{32}$  and  $R_{33}$  together represent lower alkylene so as to form a ring together with the carbon to which they are attached;

R<sub>34</sub> is hydrogen or lower alkyl;

X<sub>2</sub>, Y<sub>1</sub>, Ar, Q, Z, n and p are as defined in claim 2; and pharmaceutically acceptable salts and esters thereof, for use as a pharmaceutical.

- 7. A compound of formula III as defined in claim 6, wherein R<sub>30</sub> is an acyl group derived from an organic carboxylic, carbamic or sulfonic acid, and pharmaceutically acceptable salts and esters thereof.
- 8. A compound according to claim 7, wherein
  - (a) p is one;
  - (b)  $Y_1$  is O, S, SO, SO<sub>2</sub>,  $N(R_6)$ SO<sub>2</sub> or N-R<sub>6</sub>; and
  - (c) X<sub>2</sub> is lower alkylene; or when n is zero, X<sub>2</sub> is also C<sub>2</sub>-C<sub>7</sub>-alkylene interrupted by O, S, SO, SO<sub>2</sub> or NR<sub>6</sub>,

and pharmaceutically acceptable salts and esters thereof...

9. A compound according to claim 2, of formula IV

$$R_{40} - C - NH - C - CO - NH - C - C = N$$

$$R_{42} - C - CO - NH - C - C = N$$

$$R_{43} - R_{45}$$

$$R_{45} - C - C = N$$

$$R_{45} - C - C = N$$

$$R_{45} - C - C = N$$

wherein

R<sub>40</sub> is substituted phenyl or heterocyclic aryl, (mono- or di- carbocyclic or heterocyclic aryl)-lower alkyl or lower alkenyl, or heterocyclyl;

R<sub>42</sub> is hydrogen or lower alkyl;

R<sub>43</sub> is carbocyclic or heterocyclic aryl - lower alkyl;

R<sub>44</sub> and R<sub>45</sub> are independently hydrogen or lower alkyl; or

R<sub>44</sub> and R<sub>45</sub> combined represent lower alkylene;

and pharmaceutically acceptable salts and esters thereof.

10. A compound according to claim 3 of formula V, V' or V"

wherein the symbols are as defined above, and physiologically-acceptable and -cleavable esters or salts thereof.

- 11. A process for the preparation of a compound of formula I as defined in claim 2, comprising
  - (a) converting an amide of the formula VI

wherein R, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub> and R<sub>5</sub> have meaning as previously defined in claim 2 for the compounds of formula I to a nitrile of formula I; or

(b) condensing a compound of the formula VII

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$$NH_2-C-C \equiv N$$

$$R_5$$

$$VII$$

wherein R<sub>4</sub> and R<sub>5</sub> have meaning as defined in claim 1, with an acid of formula VIII

$$\begin{array}{c|c} R & R_3 \\ \hline \\ X_1 - NH - C - COOH \\ R_2 \\ \hline \end{array}$$

wherein R, R<sub>2</sub> and R<sub>3</sub> have meaning as defined in claim 1; or with a reactive derivative thereof; or

(c) condensing a compound of the formula Ia

$$\begin{array}{c|cccc} R_3 & R_4 \\ & & | \\ & & | \\ H_2N\text{-C-CONH-C-C} \hline \hline & N & \text{(Ia)} \\ & & | & | \\ & R_2 & R_5 & \\ \end{array}$$

wherein  $R_2$ ,  $R_3$ ,  $R_4$  and  $R_5$  have meaning as defined in claim 1 with an acid corresponding to the group R-[L]<sub>x</sub>-X<sub>1</sub>- or with a reactive derivative thereof; and in the above processes, if required, temporarily protecting any interfering reactive groups and then isolating the resulting compound of the invention; and, if desired, converting any resulting compound into another compound of the invention; and/or if desired, converting a resulting compound into a salt or a resulting salt into the free acid or base or into another salt.

12. A method of inhibiting cathersin activity in a mammal which comprises administering to a mammal in need thereof an effective amount of a compound of formula I as defined in claim 2.

- 13. A method of treating cathepsin dependent conditions in a mammal which comprises administering to a mammal in need thereof an effective amount of a compound of formula I as defined in claim 2.
- 14. A method according to claim 13 of treating inflammation, osteoporosis, rheumatoid arthritis and osteoarthritis.
- 15. A cathepsin inhibiting pharmaceutical composition which comprises a compound of formula I as defined in claim 2 as an active ingredient.

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# **PCT**

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# INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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$$R = \begin{bmatrix} 1 \\ 1 \end{bmatrix} \times \begin{bmatrix} 1 \end{bmatrix} \times \begin{bmatrix} 1 \\ 1 \end{bmatrix} \times \begin{bmatrix} 1$$

### (57) Abstract

N-terminal substituted dipeptide nitriles as defined are useful as inhibitors of cysteine cathepsins, e.g. cathepsins B, K, L and S, and can be used for the treatment of cysteine cathepsin dependent diseases and conditions, including inflammation, rheumatoid arthritis, osteoarthritis, osteoporosis, tumors (especially tumor invasion and tumor metastasis), coronary disease, atherosclerosis (including atherosclerotic plaque rupture and destabilization). Particular dipeptide nitriles are compounds of formula (I), or physiologically-acceptable and -cleavable esters or salts thereof, wherein: the symbols are as defined. In particular it has been found that by appropriate choice of groups R, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, X<sub>1</sub>, Y and L, the relative selectivity of the compounds as inhibitors of the various cysteine cathepsin types, e.g. cathepsins B, K, L and S, may be altered, e.g. to obtain inhibitors which selectively inhibit a particular cathepsin type or combination of cathepsin types.

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# **DIPEPTIDE NITRILES**

This invention relates to inhibitors of cysteine proteases, in particular to dipeptide nitrile cathepsin inhibitors and to their pharmaceutical use for the treatment or prophylaxis of diseases or medical conditions in which cathepsins are implicated.

The cysteine cathepsins, e.g. cathepsins B, K, L and S, are a class of lysosomal enzymes which are implicated in various disorders including inflammation, rheumatoid arthritis, osteoarthritis, osteoporosis, tumors (especially tumor invasion and tumor metastasis), coronary disease, atherosclerosis (including atherosclerotic plaque rupture and destabilization), autoimmune diseases. respiratory diseases. infectious diseases and immunologically mediated diseases (including transplant rejection).

In accordance with the invention it has been found that dipeptide nitriles are particularly useful as cysteine cathepsin inhibitors and can be used for the treatment of the above-cited cysteine cathepsin dependent conditions.

Accordingly the present invention provides an N-terminal-substituted dipeptide nitrile, i.e. a dipeptide in which the C-terminal carboxy group of the dipeptide is replaced by a nitrile group (-C=N) and in which the N-terminal nitrogen atom is substituted via a peptide or pseudopeptide linkage which optionally additionally comprises a -methylene-hetero atom- linker or an additional hetero atom, directly by aryl, lower alkyl, lower alkenyl, lower alkynyl or heterocyclyl, or a physiologically-acceptable and -cleavable ester or a salt thereof, for use as a pharmaceutical.

The invention further provides a pharmaceutical composition comprising an N-terminal-substituted dipeptide nitrile as defined above as an active ingredient.

The invention also provides a method of treating a patient suffering from or susceptible to a disease or medical condition in which a cathepsin is implicated, comprising administering an effective amount of an N-terminal-substituted dipeptide nitrile as defined above to the patient.

The invention further includes the use of an N-terminal-substituted dipeptide nitrile as defined above for the preparation of a medicament for therapeutic or prophylactic treatment of a disease or medical condition in which a cathepsin is implicated.

The dipeptide nitrile of the invention conveniently comprises  $\alpha$ -amino acid residues, including both natural and unnatural  $\alpha$ -amino acid residues. Herein the "natural  $\alpha$ -amino acid residues" denote the 20 amino acids obtainable by translation of RNA according to the genetic code or the corresponding nitriles thereof, as appropriate. "Unnatural  $\alpha$ -amino acid residues" are  $\alpha$ -amino acids which have  $\alpha$ -substituents other than those found in "natural  $\alpha$ -amino acid residues". Preferred  $\alpha$ -amino acid residues, as the C-terminal amino acid residue of the dipeptide nitrile, are the nitriles of tryptophan, 2-benzyloxymethyl-2-amino-acetic acid, 2,2-dimethyl-2-amino-acetic acid, 2-butyl-2-amino-acetic acid, methionine, leucine, lysine, alanine, phenylalanine, and glycine and derivatives thereof, e.g. as hereinafter described. Preferred amino acid residues as the N-terminal amino acid residue of the dipeptide nitrile are 1-amino-cyclohexanecarboxylic acid, 1-amino-cycloheptanecarboxylic acid, phenylalanine, histidine, tryptophan and leucine and derivatives thereof, e.g. as hereinafter described.

The aryl, lower alkyl, lower alkenyl, lower alkynyl or heterocyclyl substituent (hereinafter referred to as R) is attached to the the N-terminal nitrogen atom of the dipeptide via a peptide linkage, i.e. as R-C(O)-NH-, or via a pseudopeptide linkage. Suitable pseudopeptide linkages include sulphur in place of oxygen and sulphur and phosporous in place of carbon, e.g. as R-C(S)-NH-, R-S(O)-NH-, R-S(O)<sub>2</sub>-NH- or R-P(O)<sub>2</sub>-NH and analogues thereof. Additionally the peptide or pseudopeptide linkage between the R substituent and the N-terminal nitrogen atom may comprise an additional hetero atom, e.g. as R-Het-C(O)-NH-, or a -methylene-hetero atom- linker, e.g. as R-Het-CH<sub>2</sub>-C(O)-NH- or R-CH<sub>2</sub>-Het-C(O)-NH-, wherein Het is a hetero atom selected from O, N or S, and pseudopeptide containing alternatives thereof, e.g. as defined above. When the linkage between the aryl substituent and the N-terminal nitrogen atom comprises a -methylene-hetero atom- linker, the methylene group and the hetero atom may be optionally further substituted, e.g. as hereinafter described.

The R substituent may be further substituted, e.g. by up to 3 substituents selected from halogen, hydroxy, amino, nitro, optionally substituted C<sub>1-4</sub>alkyl (e.g. alkyl substituted by hydroxy, alkyloxy, amino, optionally substituted alkylamino, optionally substituted dialkylamino, aryl or heterocyclyl), C<sub>1-4</sub>alkoxy, C<sub>2-6</sub>alkenyl, CN, trifluoromethyl, trifluoromethoxy, aryl, (e.g. phenyl or phenyl substituted by CN, CF<sub>3</sub>, halogen, OCH<sub>3</sub>), aryloxy, (e.g. phenoxy or phenoxy substituted by CN, CF<sub>3</sub>, halogen, OCH<sub>3</sub>), benzyloxy or a heterocyclic residue.

Accordingly in preferred embodiments the invention provides a compound of formula I, or a physiologically-acceptable and -cleavable ester or a salt thereof

$$R = \begin{bmatrix} \\ \\ \\ \\ \\ \\ \end{bmatrix} X_1 - NH = \begin{bmatrix} \\ \\ \\ \\ \\ \\ \end{bmatrix} C - NH = \begin{bmatrix} \\ \\ \\ \\ \\ \end{bmatrix} C = \begin{bmatrix} \\ \\ \\ \\ \\ \end{bmatrix} N$$

wherein:

R is optionally substituted (aryl, lower alkyl, lower alkenyl, lower alkynyl, or heterocyclyl);

R<sub>2</sub> and R<sub>3</sub> are independently hydrogen, or optionally substitued [lower alkyl, cycloalkyl,

bicycloalkyl, or (aryl, biaryl, cycloalkyl or bicycloalkyl)-lower alkyl]; or

R<sub>2</sub> and R<sub>3</sub> together represent lower alkylene, optionally interrupted by O, S or NR<sub>6</sub>, so as to

form a ring with the carbon atom to which they are attached

wherein R<sub>6</sub> is hydrogen, lower alkyl or aryl-lower alkyl; or

either R<sub>2</sub> or R<sub>3</sub> are linked by lower alkylene to the adjacent nitrogen to form a ring;

R<sub>4</sub> and R<sub>5</sub> are independently |H, or optionally substituted (lower alkyl, aryl-lower alkyl), -

 $C(O)OR_7$ , or  $-C(O)NR_7$ R<sub>8</sub>,

wherein

R<sub>7</sub> is optionally substituted (lower alkyl, aryl, aryl-lower alkyl, cycloalkyl, bicycloalkyl or heterocyclyl), and

R<sub>8</sub> is H, or optionally substituted (lower alkyl, aryl, aryl-lower alkyl, cycloalkyl, bicycloalkyl or heterocyclyl), or

R<sub>4</sub> and R<sub>5</sub> together represent lower alkylene, optionally interrupted by O, S or NR<sub>6</sub>, so as to form a ring with the carbon atom to which they are attached wherein R<sub>6</sub> is hydrogen, lower alkyl or aryl-lower alkyl, or

 $R_4$  is H or optionally substituted lower alkyl and  $R_5$  is a substituent of formula  $-X_2-(Y_1)_{n-1}$ 

$$(Ar)_p$$
-Q-Z

wherein

Y<sub>1</sub> is O, S, SO, SO<sub>2</sub>, N(R<sub>6</sub>)SO<sub>2</sub>, N-R<sub>6</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub> or NR<sub>6</sub>CO; n is zero or one;

p is zero or one;

X<sub>2</sub> is lower alkylene; or when n is zero, X<sub>2</sub> is also C<sub>2</sub>-C<sub>7</sub>-alkylene interrupted by O, S, SO, SO<sub>2</sub>, NR<sub>6</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub> or NR<sub>6</sub>CO;

wherein R<sub>6</sub> is hydrogen, lower alkyl or aryl-lower alkyl;

Ar is arylene;

Z is hydroxy, acyloxy, carboxyl, esterified carboxyl, amidated carboxyl, aminosulfonyl, (lower alkyl or aryl-lower alkyl)aminosulfonyl, or (lower alkyl or aryl-lower alkyl)sulfonylaminocarbonyl; or Z is tetrazolyl, triazolyl or imidazolyl;

Q is a direct bond, lower alkylene,  $Y_1$ -lower alkylene or  $C_2$ - $C_7$ -alkylene interrupted by  $Y_1$ ;

 $X_1$  is -C(O)-, -C(S)-, -S(O)-, -S(O)<sub>2</sub>-, -P(O)(OR<sub>6</sub>)-

wherein R<sub>6</sub> is as defined above;

Y is oxygen or sulphur;

L is optionally substituted -Het-, -Het-CH<sub>2</sub>- or -CH<sub>2</sub> Het-, wherein Het is a hetero atom selected from O, N or S, and

x is zero or one;

and aryl in the above definitions represents carbocyclic or heterocyclic aryl, for use as a pharmaceutical;

a pharmaceutical composition comprising a compound of formula I as defined above as an active ingredient;

a method of treating a patient suffering from or susceptible to a disease or medical condition in which a cathepsin is implicated, comprising administering an effective amount of a compound of formula I as defined above to the patient; and

use of a compound of formula I as defined above for the preparation of a medicament for therapeutic or prophylactic treatment of a disease or medical condition in which a cathepsin is implicated.

The invention also provides novel dipeptide nitriles.

Accordingly the invention further provides a compound of formula I as defined above

provided that when R is lower alkyl not substituted by aryl,

one of  $R_4$  or  $R_5$  is a substituent of formula  $-X_2-(Y_1)_n-(Ar)_p-Q-Z$ ,

provided that when x is one, L is -O-, or -CH<sub>2</sub>-O- and X<sub>1</sub> is -C(O)-,

either one of  $R_4$  or  $R_5$  is a substituent of formula  $-X_2-(Y_1)_n-(Ar)_p-Q-Z$ , or R is not unsubstituted phenyl,

provided that when  $R_2 = R_4 + R_5 = H$ , x is zero and  $X_1$  is -C(O)-,

R<sub>3</sub> is not H, -CH<sub>3</sub>, -CH<sub>2</sub>(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-COOH, or -CH<sub>2</sub>-COO-CH<sub>2</sub>-CH<sub>3</sub>, when R is unsubstituted phenyl,

R<sub>3</sub> is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when R is 4-aminophenyl or 4-nitrophenyl,

R<sub>3</sub> is not H when R is 3-aminophenyl, 3-nitrophenyl 2-chloropyridin-4-yl, or vinyl or R<sub>3</sub> is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when R is pyridin-3-yl or 2-chloropyridin-4-yl,

provided that when  $R_2 = R_3 \stackrel{!}{=} R_4 = H$ , x is zero and  $X_1$  is -C(O)- and R is phenyl,

 $R_5$  is not  $-CH(CH_3)_2$ ,

provided that when  $R_3 = R_4 \stackrel{!}{=} H$ ,  $R_5$  is -CH<sub>2</sub>-COOH, x is zero and  $X_1$  is -C(O)-,

 $R_2$  does not form a heterocyclic ring with the adjacent nitrogen atom, and provided that when  $R_2 = R_3 = R_4 = R_5 = H$ , x is zero and  $X_1$  is -SO<sub>2</sub>-,

R is not 4-methylphenyl.

In formula I R, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub> and L may be further substituted by one or more, e.g. up to 3. substituents independently selected from lower alkyl, aryl, aryl-lower alkyl, cycloalkyl, heterocyclyl, -CN, -halogen, -OH, -NO<sub>2</sub>, -NR<sub>9</sub>R<sub>10</sub>, -X<sub>3</sub>-R<sub>7</sub>, lower alkyl-X<sub>3</sub>-R<sub>8</sub>, halosubstituted lower alkyl,

wherein R<sub>7</sub> and R<sub>8</sub> are as defined above,

 $X_3$  is -O-, -S-, -NR<sub>8</sub>-, -C(O)-, -C(S)-, -S(O)-, -S(O)<sub>2</sub>-, -C(O)O-, -C(S)O-, -C(O)NR<sub>8</sub>-,

wherein R<sub>8</sub> is as defined above,

 $R_9$  and  $R_{10}$  are independently as defined above for  $R_8$ , or  $-X_4-R_8$ ,

wherein  $X_4$  is -C(O)-, -C(S)-, -S(O)-, -S(O)<sub>2</sub>-, -C(O)O-, -C(S)O-, -C(O)NR<sub>6</sub>-wherein  $R_6$  and  $R_7$  are as defined above, or

 $R_9$  and  $R_{10}$  together with N form a heteroaryl group or a saturated or unsaturated heterocycloalkyl group, optionally containing one or more additional heteroatoms selected from O, N or S.

Compounds of formula I exhibit valuable pharmacological properties in mammals, in particular as cysteine cathepsin inhibitors. In accordance with the present invention it has been found that by appropriate choice of groups R, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, X<sub>1</sub>, Y and L, the relative selectivity of the compounds as inhibitors of the various cysteine cathepsin types, e.g. cathepsins B, K, L and S may be altered, e.g. to obtain inhibitors which selectively inhibit a particular cathepsin type or combination of cathepsin types.

In a first aspect the invention provides a compound of formula II, or a physiologically-acceptable and -cleavable ester or a salt thereof

$$R_{20} = L' - X_1 - NH + C - N - C = N$$

$$R_{22} = 1 - N - R_{24} - R_{25} - R_{25}$$

wherein:

R<sub>20</sub> is optionally substituted (aryl, aryl-lower alkyl, lower alkenyl, lower alkynyl, heterocyclyl, or heterocyclyl-lower alkyl);

R<sub>22</sub> is H, or optionally substitued lower alkyl, and

R<sub>23</sub> is optionally substituted (lower alkyl, aryl-lower alkyl, or cyloalkyl-lower alkyl) or

R<sub>22</sub> and R<sub>23</sub> together with the carbon atom to which they are attached form an optionally substituted (cycloalkyl group or heterocycloalkyl group);

 $R_{24}$  and  $R_{25}$  are independently H, or optionally substituted (lower alkyl, or aryl-lower alkyl).  $-C(O)OR_7, \, or \, -C(O)NR_7R_8$ 

wherein R<sub>7</sub> and R<sub>8</sub> are as defined above, or

R<sub>24</sub> and R<sub>25</sub> together with the carbon atom to which they are attached form an optionally substituted (cycloalkyl group or heterocycloalkyl group);

 $X_1$  is as defined above;

Y is oxygen or sulphur;

L' is optionally substituted (-Het-CH<sub>2</sub>- or -CH<sub>2</sub>-Het-),

wherein Het is a a hetero atom selected from O, N or S, and

x is 1 or 0,

provided that when x is one,  $\coprod$  is -CH<sub>2</sub>-O- and X<sub>1</sub> is -C(O)-,

R<sub>20</sub> is not unsubstituted phenyl,

provided that when  $R_{22} = R_{24} \stackrel{\perp}{=} R_{25} = H$ , x is zero and  $X_1$  is -C(O)-,

R<sub>23</sub> is not H, -CH<sub>3</sub>, -CH(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-COOH, or -CH<sub>2</sub>-COO-CH<sub>2</sub>-CH<sub>3</sub>, when R<sub>20</sub> is unsubstituted phenyl,

 $R_{23}$  is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when  $R_{20}$  is 4-aminophenyl or 4-nitrophenyl,

R<sub>23</sub> is not H when R<sub>20</sub> is 3-aminophenyl, 3-nitrophenyl 2-chloropyridin-4-yl, or vinyl, or

R<sub>23</sub> is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when R<sub>20</sub> is pyridin-3-yl or 2-chloropyridin-4-yl,

provided that when  $R_{22} = R_{23} \stackrel{\perp}{=} R_{24} = H$ , x is zero and  $X_1$  is -C(O)- and  $R_{20}$  is phenyl,

 $R_{25}$  is not -CH(CH<sub>3</sub>)<sub>2</sub>,

provided that when  $R_{23} = R_{24} = H$ ,  $R_{25}$  is -CH<sub>2</sub>-CH<sub>2</sub>-COOH, x is zero and  $X_1$  is -C(O)-,

 $R_{22}$  does not form a heterocyclic ring with the adjacent nitrogen atom, and provided that when  $R_{22} = R_{23} = R_{24} = R_{25} = H$ , x is zero and  $X_1$  is -SO<sub>2</sub>-,

R<sub>20</sub> is not 4-methylphenyl.

Compounds of formula II are typically inhibitors of cathepsins K, L or S, especially selective inhibitors of catepsin K or cathepsin L or cathepsin S, or in some case inhibitors of, e.g. cathepsins L and S.

The substituents of the compounds of formula II have the following preferred significances.

Preferred compounds of formula II comprise compounds having preferred substituents, singly or in any combination.

Preferably when R<sub>20</sub> comprises aryl, the aryl is optionally substituted (phenyl, naphthylenyl, phenanthrenyl, thiophenyl, furanyl, pyrrolyl, pyrazolyl, thiazolyl, pyridinyl, indolyl, quinolinyl, isoquinolinyl, benzothienyl and benzofuranyl).

Preferably R<sub>22</sub> is hydrogen.

Preferably  $R_{23}$  is optionally substituted (lower alkyl, aryl-lower alkyl or cycloalkyl-lower alkyl), or  $R_{23}$  and  $R_{22}$  together with the carbon atom to which they are attached form a  $C_5$ - $C_8$ , especially a  $C_6$  or  $C_7$ , cycloalkylgroup. More preferably  $R_{23}$  is -CH<sub>2</sub>-CH(CH<sub>3</sub>)<sub>2</sub>, or optionally substituted benzyl, cyclohexylmethyl, naphthalenylmethyl, indolylmethyl, benzothienylmethyl or benzofuranylmethyl, or  $R_{23}$  and  $R_{22}$  together with the carbon atom to which they are attached form a cyclohexane ring.

Preferred significances for R<sub>24</sub> and R<sub>25</sub> are:

R<sub>24</sub> and R<sub>25</sub> are both H or -CH<sub>3</sub>, or

R<sub>24</sub> is H and R<sub>25</sub> is aryl-lower alkyl, lower alkyl, both optionally substitued by up to 3 substituents selected from amino, halogen (e.g. fluorine or preferably chlorine) or S-CH<sub>3</sub>, or

R<sub>24</sub> and R<sub>25</sub> together with the carbon atom to which they are attached form a C<sub>3</sub>-C<sub>7</sub> cycloalkyl ring.

More preferably  $R_{24}$  is H and  $R_{25}$  is optionally substituted (-CH<sub>2</sub>-phenyl, -CH<sub>2</sub>-indolyl, -(CH<sub>2</sub>)<sub>2</sub>-S-CH<sub>3</sub>, -CH<sub>2</sub>-CH(CH<sub>3</sub>)<sub>2</sub>, -(CH<sub>2</sub>)<sub>4</sub>-NH<sub>2</sub> or -(CH<sub>2</sub>)<sub>3</sub>-CH<sub>3</sub>), or yet more preferably  $R_4$  and  $R_5$  are both - CH<sub>3</sub>, or especially  $R_4$  and  $R_5$  are both H.

Preferably  $-X_1$ - is -C(O)-.

Preferably Y is =0.

Preferably either x is 0, or when x is 1 L' is -CH<sub>2</sub>-O-, NH-CH<sub>2</sub>-, -O-CH<sub>2</sub>- or -S-CH<sub>2</sub>.

In particular embodiments the invention provides a compound of formula II' or a physiologically-acceptable and -cleavable ester or a salt thereof

$$R_{20} = L' - X_1 - NH + C - N - R_{23}' - C = N$$

$$X_1 - NH + C - N - R_{22}' - C = N$$

$$R_{20} = 1 - N - R_{23}' - R_{25}' -$$

wherein:

 $R_{20}$ ' is optionally substituted ( $C_6$ - $C_{18}$  aryl or  $C_4$ - $C_{18}$  heteroaryl);

R<sub>22</sub>' is H, or optionally substitued C<sub>1</sub>-C<sub>8</sub> alkyl, and

 $R_{23}$ ' is optionally substituted ( $C_2$ - $C_8$  alkyl, or  $C_7$ - $C_{14}$  aralkyl), or

R<sub>22</sub>' and R<sub>23</sub>' together with the carbon atom to which they are attached form an optionally substituted (C<sub>3</sub>-C<sub>8</sub> cycloalkyl group or C<sub>4</sub>-C<sub>7</sub> heterocycloalkyl group);

R<sub>24</sub>' and R<sub>25</sub>' are independently H, or optionally substituted (C<sub>1</sub>-C<sub>8</sub> alkyl, C<sub>7</sub>-C<sub>14</sub> aralkyl, or C<sub>5</sub>-C<sub>14</sub> heteroaralkyl), -C(O)OR<sub>6</sub>', or -C(O)NR<sub>6</sub>'R<sub>7</sub>' wherein

 $R_6$ ' is optionally substituted ( $C_1$ - $C_8$  alkyl,  $C_7$ - $C_{14}$  aralkyl,  $C_3$ - $C_8$  cycloalkyl,  $C_4$ - $C_7$  heterocycloalkyl,  $C_5$ - $C_{14}$  heteroaralkyl,  $C_6$ - $C_{14}$  aryl, or  $C_4$ - $C_{14}$  heteroaryl), and  $R_7$ ' is H, or optionally substituted ( $C_1$ - $C_8$  alkyl,  $C_7$ - $C_{14}$  aralkyl,  $C_3$ - $C_8$  cycloalkyl,  $C_4$ - $C_7$  heterocycloalkyl,  $C_5$ - $C_{14}$  heteroaralkyl,  $C_6$ - $C_{14}$  aryl, or  $C_4$ - $C_{14}$  heteroaryl), or

R<sub>24</sub>' and R<sub>25</sub>' together with the carbon atom to which they are attached form an optionally substituted (C<sub>3</sub>-C<sub>8</sub> cycloalkyl group or C<sub>4</sub>-C<sub>7</sub> heterocycloalkyl group);

 $X_1$  is -C(O)-, -C(S)-, -S(O)-, -S(O)<sub>2</sub>-, -P(O)(OR<sub>6</sub>')wherein R<sub>6</sub>' is as defined above;

Y is oxygen or sulphur;

L' is optionally substituted (-Het-CH<sub>2</sub>- or -CH<sub>2</sub>-Het-),
wherein Het is a a hetero atom selected from O, N or S, and
x is 1 or 0,

provided that when x is one, L' is -CH<sub>2</sub>-O- and X<sub>1</sub> is -C(O)-

R<sub>20</sub>' is not unsubstituted phenyl,

provided that when  $R_{22}' = R_{24}' = R_{25}' = H$ , x is zero and  $X_1$  is -C(O)-,

 $R_{23}$ ' is not H,  $-CH_3$ ,  $-CH(CH_3)_2$ ,  $-CH_2$ -CH- $(CH_3)_2$ ,  $-CH_2$ -COOH, or  $-CH_2$ -COO- $CH_2$ -CH<sub>3</sub>, when  $R_{20}$ ' is unsubstituted phenyl,

R<sub>23</sub>' is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when R<sub>20</sub>' is 4-aminophenyl or 4-nitrophenyl,

R<sub>23</sub>' is not H when R<sub>20</sub>' is 3-aminophenyl, 3-nitrophenyl, 2-chloropyridin-4-yl, or vinyl.

 $R_{23}$ ' is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when  $R_{20}$ ' is pyridin-3-yl or 2-chloropyridin-4-yl. provided that when  $R_{22}$ ' =  $R_{23}$ ' =  $R_{24}$ ' = H, x is zero and  $X_1$  is -C(O)- and  $R_{20}$ ' is phenyl,  $R_{25}$ ' is not -CH(CH<sub>3</sub>)<sub>2</sub>,

provided that when  $R_{23}' = R_{24}' = H$ ,  $R_{25}'$  is  $-CH_2-CH_2-COOH$ , x is zero and  $X_1$  is -C(O)-,

 $R_{20}$ ' does not form a heterocyclic ring with the adjacent nitrogen atom, and provided that when  $R_{22}$ ' =  $R_{23}$ ' =  $R_{24}$ ' =  $R_{25}$ ' H, x is zero and  $X_1$  is -SO<sub>2</sub>-,  $R_{20}$ ' is not 4-methylphenyl.

Compounds of formula II' are typically selective inhibitors of cathepsin K.

In a further aspect the invention provides a compound of formula III

wherein

 $R_{30}$  is an acyl group derived from an organic carboxylic, carbonic, carbamic or sulfonic acid;  $R_{32}$  and  $R_{33}$  are independently hydrogen, lower alkyl, cycloalkyl, bicycloalkyl, or (aryl, biaryl, cycloalkyl or bicycloalkyl)-lower alkyl; or  $R_{32}$  and  $R_{33}$  together represent lower alkylene so as to form a ring together with the carbon to which

R<sub>34</sub> is hydrogen or lower alkyl;

X<sub>2</sub>, Y<sub>1</sub>, Ar, Q, Z, n and p are as previously defined; and pharmaceutically acceptable salts and esters thereof for use as a pharmaceutical.

In preferred embodiments the invention further provides a compound of formula III as defined above, wherein R<sub>30</sub> is an acyl group derived from an organic carboxylic, carbamic or sulfonic acid

Compounds of formula III are typically selective inhibitors of cathepsin B and/or L.

Particular embodiments relate to the compounds of formula III wherein  $R_{30}$ ,  $R_{32}$ ,  $R_{33}$ ,  $R_{34}$ , Q, Z and n are as defined above; and wherein

- (a) p is one;
- (b)  $Y_1$  is O, S, SO,  $SO_2$ ,  $N(R_6)SO_2$  or N- $R_6$ ; and

(c) X<sub>2</sub> is lower alkylene; or when n is zero, X<sub>2</sub> is also C<sub>2</sub>-C<sub>7</sub>-alkylene interrupted by O, S, SO, SO<sub>2</sub> or NR<sub>6</sub>;

wherein N<sub>6</sub> is as defined above and pharmaceutically acceptable salts thereof.

Further particular embodiments relate to the compounds of formula III wherein R<sub>30</sub>, R<sub>32</sub>, R<sub>33</sub>, R<sub>34</sub>, R<sub>35</sub>, Ar, Z and Q have meaning as defined above; and wherein

- (a) p is one, n is zero, and X<sub>2</sub> is lower alkylene or C<sub>2</sub>-C<sub>7</sub>-alkylene interrupted by O, S, SO, SO<sub>2</sub> NR<sub>6</sub>, NR<sub>6</sub>SO<sub>2</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub> or NR<sub>6</sub>CO; or
- (b) p is one, n is one, X<sub>2</sub> is lower alkylene and Y<sub>1</sub> is O, S, SO, SO<sub>2</sub>, N(R<sub>6</sub>)SO<sub>2</sub> or NR<sub>6</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub>, NR<sub>6</sub>CO; or
- (c) p is one, n is zero and X<sub>2</sub> is lower alkylene; or
- (d) p is one, n is zero and X<sub>2</sub> is C<sub>2</sub>-C<sub>7</sub>-alkylene interrupted by O, S, SO, SO<sub>2</sub> or NR<sub>6</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub> or NR<sub>6</sub>CO; or
- (e) p is zero, n is one, X<sub>2</sub> is lower alkylene and Y<sub>1</sub> is O, S, SO, SO<sub>2</sub>, N(R<sub>6</sub>)SO<sub>2</sub> or NR<sub>6</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub> or NR<sub>6</sub>CO; or
- (f) p is zero, n is zero and X<sub>2</sub> is C<sub>2</sub>-C<sub>7</sub>-alkylene interrupted by O, S, SO, SO<sub>2</sub> or NR<sub>6</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub> or NR<sub>6</sub>CO;

and pharmaceutically acceptable salts thereof: or

Preferred compounds of formula III are those in which Z is carboxyl or carboxyl derivatized as a pharmaceutically acceptable ester.

A particular embodiment of the invention relates to the compounds of formula III wherein n is zero, in particular those of formula III'

$$R_{30}$$
 NH— CH— CONH— CH— C $\equiv$  N III'  $R_{33}$ '  $X_2$ — (Ar)p—Q—Z'

wherein

R<sub>30</sub>, X<sub>2</sub>, Ar, Q, and p are as defined above; and wherein R<sub>33</sub>' is carbocyclic or heterocyclic aryl-lower alkyl;

Z' is hydroxy, acyloxy, carboxyl, carboxyl derivatized as a pharmaceutically acceptable ester or amide, or 5-tetrazolyl;

and pharmaceutically acceptable salts thereof.

In a specific embodiment of the compounds of formula III',  $R_{30}$  is carboxylic acid derived acyl;  $R_{33}$ ' is carbocyclic or heterocyclic aryl-lower alkyl;  $X_2$  is  $C_1$ - $C_5$ -alkylene, or  $X_2$  is  $C_2$ - $C_4$ -alkylene interrupted by O or S; p is one; Ar is carbocyclic arylene; Q is a direct bond or  $C_1$ - $C_4$ -alkylene; and Z is carboxyl or carboxyl derivatized as a pharmaceutically acceptable ester; and pharmaceutically acceptable salts thereof.

In a more specific embodiment of the compounds of formula III',  $R_{30}$  is aroyl,  $R_{33}$ ' is carbocyclic aryl-methyl;  $X_2$  is  $C_3$ -alkylene; or  $X_2$  is  $C_2$ -alkylene interrupted by O; p is one; Ar is phenylene; Q is a direct bond; and Z is carboxyl; and pharmaceutically acceptable salts thereof.

A further particular embodiment of the invention relates to the compounds of formula III wherein n is one, in particular those of formula III"

$$R_{30}$$
 NH—CH—CONH—CH—C $\equiv$  N III'  
 $R_{33}$ '  $X_2$ '-Y—Ar—Q—Z'

wherein

R<sub>30</sub>, R<sub>33</sub>', Y<sub>1</sub>, Ar, and Z' are as defined above;

X<sub>2</sub>' is lower alkylene;

Q' is a direct bond or lower alkylene;

and pharmaceutically acceptable salts thereof.

A specific embodiment of the invention is directed to the compounds of formula III" wherein  $R_{30}$  is carboxylic acid derived acyl;  $R_{33}$ ' is carbocyclic or heterocyclic aryl-lower alkyl;  $X_2$ ' is  $C_1$ - $C_4$ -alkylene;  $Y_1$  is O or S; Ar is carbocyclic arylene; Q' is a direct bond or  $C_1$ - $C_4$ -alkylene; and  $Z^*$  is carboxyl or carboxyl derivatized as a pharmaceutically acceptable ester; and pharmaceutically acceptable salts thereof.

A more specific embodiment of the invention is directed to said compounds of formula III" wherein  $R_{30}$  is aroyl,  $R_{33}$  is carbocyclic aryl-methyl;  $X_2$  is  $C_2$ -alkylene;  $Y_1$  is O; Ar is phenylene; Q is a direct bond; and Z is carboxyl, and pharmaceutically acceptable salts thereof.

A yet further aspect of the invention is directed to a compound of formula IV

$$R_{40} - C - NH - C - CO - NH - C - C = N$$

$$R_{42} - C - C = N$$

$$R_{43} - C - C = N$$

$$R_{43} - C - C = N$$

$$R_{45} - C = N$$

wherein

R<sub>40</sub> is substituted phenyl or heterocyclic aryl, (mono- or di- carbocyclic or heterocyclic aryl)-lower alkyl or lower alkenyl, or heterocyclyl;

R<sub>42</sub> is hydrogen or lower alkyl;

R<sub>43</sub> is carbocyclic or heterocyclic aryl - lower alkyl;

R<sub>44</sub> and R<sub>45</sub> are independently hydrogen or lower alkyl; or

R<sub>44</sub> and R<sub>45</sub> combined represent lower alkylene;

and pharmaceutically acceptable salts and esters thereof.

Preferred are compounds of formula IV wherein R<sub>40</sub> is morpholino, substituted phenyl or heterocyclic aryl; R<sub>42</sub> is hydrogen; R<sub>43</sub> is carbocyclic or heterocyclic aryl-lower alkyl; R<sub>44</sub> and R<sub>45</sub> are hydrogen or lower alkyl; or R<sub>44</sub> and R<sub>45</sub> combined represent ethylene to form a cyclopropyl ring.

Particularly preferred are compounds of formula IV wherein R<sub>40</sub> is pyrazolyl or pyrazolyl substituted by 1-3 lower alkyl; R<sub>42</sub> is hydrogen; R<sub>43</sub> is carbocyclic or heterocyclic aryl-C<sub>1</sub>-C<sub>4</sub>-alkyl; and R<sub>44</sub> and R<sub>45</sub> are hydrogen; or R<sub>44</sub> and R<sub>45</sub> combined are ethylene.

Compounds of formula IV are typically selective inhibitors of cathepsin L and/or S.

The compounds of formulae I, II, III and IV, depending on the nature of substituents, possess one or more asymmetric carbon atoms. The resulting diastereomers and enantiomers are encompassed by the instant invention. Preferably, however, e.g. for pharmaceutical use in accordance with the invention, the compounds of formulae I, II, III and IV are provided in pure or substantially pure epimeric form, e.g. as compositions in which the compounds are present in a form comprising at least 90%, e.g. preferably at least 95% of a single epimer (i.e. comprising less than 10%, e.g. preferably less than 5% of other epimeric forms).

Preferred compounds of formula I are those wherein the asymmetric carbon to which are attached R<sub>2</sub> and/or R<sub>3</sub> corresponds to that of an L-amino acid precursor and the asymmetric carbon to which is attached the cyano group also corresponds to that of an L-amino acid and is generally assigned the (S)-configuration. Preferred compounds of formula I wherein R<sub>3</sub> and R<sub>4</sub> represent hydrogen can be represented by formulae V, V' and V'', corresponding to preferred compounds of formulae II, III and IV respectively

Thus in particularly preferred embodiments the invention provides a compound of formula V, V' or V"

wherein the symbols are as defined above, and physiologically-acceptable and -cleavable esters or salts thereof.

The compounds of formula I, II, III', III', IV, V, V' and V" as defined above are hereinafter referred to as Compounds of the Invention.

The general definitions used herein have the following meaning within the scope of the invention, unless otherwise specified.

The term "lower" referred to above and hereinafter in connection with organic radicals or compounds respectively defines such as branched or unbranched with up to and including 7, preferably up to and including 4 and advantageously one or two carbon atoms.

A lower alkyl group is branched or unbranched and contains 1 to 7 carbon atoms, preferably 1-4 carbon atoms. Lower alkyl represents for example methyl, ethyl, propyl, butyl, isopropyl or isobutyl.

Lower alkenyl represents either straight chain or branched alkenyl of 2 to 7 carbon atoms, preferably 2-4 carbon atoms, e.g. as vinyl, propenyl, isopropenyl, butenyl, isobutenyl or butadienyl.

Lower alkynyl represents either straight chain or branched alkynyl of 2 to 7 carbon atoms, preferably 2-4 carbon atoms, e.g. as acetylenyl, propynyl, isopropynyl, butynyl or isobutynyl.

Lower alkyl, lower alkenyl and lower alkynyl may be substituted by up to 3 substituents selected from lower alkoxy, aryl, hydroxy, halogen, cyano, or trifluoromethyl.

Lower alkylene represents either straight chain or branched alkylene of 1 to 7 carbon atoms and represents preferably straight chain alkylene of 1 to 4 carbon atoms, e.g. a methylene, ethylene, propylene or butylene chain, or said methylene, ethylene, propylene or butylene chain monosubstituted by C<sub>1</sub>-C<sub>3</sub>-alkyl (advantageously methyl) or disubstituted on the same or different carbon atoms by C<sub>1</sub>-C<sub>3</sub>-alkyl (advantageously methyl), the total number of carbon atoms being up to and including 7.

A lower alkoxy (or alkyloxy) group preferably contains 1-4 carbon atoms, advantageously 1-3 carbon atoms, and represents for example ethoxy, propoxy, isopropoxy, or most advantageously methoxy.

Halogen (halo) preferably represents chloro or fluoro but may also be bromo or iodo.

An acyl group as represented by R<sub>30</sub> is preferably derived from an organic carbonic acid, an organic carboxylic acid, a carbamic acid or an organic sulfonic acid.

Acyl which is derived from a carboxylic acid represents, for example, carbocyclic or heterocyclic aroyl, cycloalkylcarbonyl, (oxa or thia)- cycloalkylcarbonyl, lower alkanoyl, (lower alkoxy, hydroxy or acyloxy)- lower alkanoyl, (mono- or di- carbocyclic or heterocyclic) - (lower alkanoyl or lower alkoxy-, hydroxy- or acyloxy- substituted lower alkanoyl), or biaroyl.

Carbocyclic aroyl represents, for instance, benzoyl, benzoyl substituted, by one to three substituents selected independently from e.g. halo, trifluoromethyl, lower alkyl, lower alkoxy, hydroxy, methylenedioxy, nitro, di-lower alkylamino, cyano, or carbocyclic aroyl represents e.g. 1-or 2-naphthoyl.

Heterocyclic aroyl represents, for instance, 2-, 3- or 4-pyridylcarbonyl (such as nicotinoyl), furoyl, thienoyl, oxazoloyl, isoxazoloyl, quinoxaloyl, each optionally substituted by e.g. halo, lower alkyl, lower alkoxy or nitro.

(Oxa - or thia)-cyclolalkylcarbonyl is, for example, tetrahydrofuranoyl or tetrahydrothienoyl.

Di-(carbocyclic or heterocyclic)aryl- lower alkanoyl is, for example, diphenylacetyl or dipyridylacetyl.

Aryl- (lower alkoxy, hydroxy or acyloxy substituted) lower alkanoyl is, for example, phenyl-(2-alkoxy, hydroxy or acyloxy)-acetyl.

Biaroyl is, for example, 2, 3 or 4-biphenylcarbonyl.

Acyl which is derived from an organic carbonic acid is, for example, alkoxycarbonyl, especially lower alkoxycarbonyl, which is unsubstituted or substituted by carbocyclic or heterocyclic aryl or is cycloalkoxycarbonyl, especially C<sub>3</sub>-C<sub>7</sub>-cycloalkyloxycarbonyl, which is unsubstituted or substituted by lower alkyl.

Acyl which is derived from a carbamic acid is, for example, aminocarbonyl which is optionally substituted on nitrogen by one or two of lower alkyl, carbocyclic or heterocyclic aryl-lower alkyl, carbocyclic or heterocyclic aryl, or by lower alkylene or lower alkylene interrupted by O or S.

Acyl which is derived from an organic sulfonic acid represents, for example, lower alkylsulfonyl, carbocyclic or heterocyclic arylsulfonyl, carbocyclic or heterocyclic aryl-lower alkysulfonyl, in which aryl is e.g. phenyl, naphthyl or thienyl, such being optionally substituted by, for example, lower alkyl, lower alkoxy, halo, nitro, trifluoromethyl, carboxyl or lower alkoxycarbonyl.

Aryl represents carbocyclic or heterocyclic aryl.

Carbocyclic aryl represents monocyclic, bicyclic or tricyclic aryl, for example phenyl or phenyl mono-, di- or tri-substituted by one, two or three radicals selected from lower alkyl, lower alkoxy, aryl, hydroxy, halogen, cyano, trifluoromethyl, lower alkylenedioxy and oxy-C<sub>2</sub>-C<sub>3</sub>-alkylene; or 1- or 2-naphthyl; or 1- or 2-phenanthrenyl. Lower alkylenedioxy is a divalent substituent attached to two adjacent carbon atoms of phenyl, e.g. methylenedioxy or ethylenedioxy. Oxy-C<sub>2</sub>-C<sub>3</sub>-alkylene is also a divalent substituent attached to two adjacent carbon atoms of phenyl, e.g. oxyethylene or oxypropylene. An example for oxy-C<sub>2</sub>-C<sub>3</sub>-alkylene-phenyl is 2,3-dihydrobenzofuran-5-yl.

Preferred as carbocyclic aryl is naphthyl, phenyl or phenyl mono- or disubstituted by lower alkoxy, phenyl, halogen, lower alkyl or trifluoromethyl, especially phenyl or phenyl mono- or disubstituted by lower alkoxy, halogen or trifluoromethyl, and in particular phenyl.

Examples of substituted phenyl groups as R are, e.g. 4-chlorophen-1-yl, 3,4-dichlorophen-1-yl, 4-methoxyphen-1-yl, 4-methylphen-1-yl, 4-aminomethylphen-1-yl, 4-methoxyethylaminomethylphen-1-yl, 4-hydroxyethyl-(methyl)-aminomethylphen-1-yl, 3-aminomethylphen-1-yl, 4-N-acetylaminomethylphen-1-yl, 4-aminophen-1-yl, 3-aminophen-1-yl, 2-aminophen-1-yl, 4-phenyl-phen-1-yl, 4-(imidazol-1-yl)-phen-1-yl, 4-(imidazol-1-yl)-phen-1-yl, 4-(imidazol-1-yl)-phen-1-yl, 4-(2-methoxyethylaminomethyl)-phen-1-yl and 4-(pyrrolidin-1-ylmethyl)-phen-1-yl, 4-(2-thiophenyl)-phen-1-yl, 4-(3-thiophenyl)-phen-1-yl, 4-(4-methylpiperazen-1-yl)-phen-1-yl, and 4-(piperidinyl)-phenyl and 4-(pyridinyl)-phenyl optionally substituted in the heterocyclic ring.

Heterocyclic aryl represents monocyclic or bicyclic heteroaryl, for example pyridyl, indolyl, quinoxalinyl, quinolinyl, isoquinolinyl, benzothienyl, benzofuranyl, benzopyranyl, benzothiopyranyl, furanyl, pyrrolyl, thiazolyl, oxazolyl, isoxazolyl, triazolyl, tetrazolyl, pyrazolyl, imidazolyl, thienyl, or any said radical substituted, especially mono- or di-substituted, by e.g. lower alkyl, nitro or halogen. Pyridyl represents 2-, 3- or 4-pyridyl, advantageously 2- or 3-pyridyl. Thienyl represents 2- or 3-thienyl. Quinolinyl represents preferably 2-, 3- or 4-quinolinyl. Isoquinolinyl represents preferably 1-, 3- or 4-isoquinolinyl. Benzopyranyl, benzothiopyranyl represent preferably 3-benzopyranyl or 3-benzothiopyranyl, respectively. Thiazolyl represents preferably 2- or 4-thiazolyl, advantageously 4-thiazolyl. Triazolyl is preferably 1-, 2- or 5-(1,2,4-triazolyl). Tetrazolyl is preferably 5-tetrazolyl.

Preferably, heterocyclic aryl is pyridyl, indolyl, quinolinyl, pyrrolyl, thiazolyl, isoxazolyl. triazolyl, tetrazolyl, pyrazolyl, imidazolyl, thienyl, or any said radical substituted, especially mono- or di-substituted, by lower alkyl or halogen; and in particular pyridyl.

Arylene (Ar in formula III) is an aryl linking group in which aryl is heterocyclic or carbocyclic aryl, preferably monocyclic as defined above.

A heterocyclic aryl linking group is for instance (but not limited thereto) 1, 3-pyrazolyl, 2,4- or 2,5-pyridyl or 1,4-imidazolyl in which the groups as depicted in formula III are attached to the ring at the indicated positions.

A carbocyclic aryl linking group is for instance (but not limited thereto) optionally substituted phenyl in which the two groups as depicted in formula I are attached ortho, meta or para to each other.

Biaryl is may be carbocyclic biaryl, preferably e.g. biphenyl, namely 2, 3 or 4-biphenyl, advantageously 4-biphenyl, each optionally substituted by e.g. lower alkyl, lower alkoxy, halogen, trifluoromethyl or cyano, or heterocyclic-carbocyclic biaryl, preferably e.g. thienylphenyl, pyrrolylphenyl and pyrazolylphenyl.

Cycloalkyl represents a saturated cyclic hydrocarbon optionally substituted by lower alkyl which contains 3 to 10 ring carbons and is advantageously cyclopentyl, cyclohexyl, cycloheptyl or cyclooctyl optionally substituted by lower alkyl.

Bicycloalkyl is for example norbornanyl.

Heterocyclyl represents a saturated cyclic hydrocarbon containing one or more, preferably 1 or 2, hetero atoms selected from O, N or S, and from 3 to 10, preferably 5 to 8, ring atoms; for example, tetrahydrofuranyl, tetrahydrothienyl, tetrahydropyrrolyl, piperidinyl, piperazinyl or morpholino.

Aryl-lower alkyl represents preferably (carbocyclic aryl or heterocylic aryl)-lower alkyl.

Carbocyclic aryl-lower alkyl represents preferably straight chain or branched aryl- $C_{1-4}$ -alkyl in which carbocyclic aryl has meaning as defined above, e.g. benzyl or phenyl-(ethyl, propyl or butyl). each unsubstituted or substituted on phenyl ring as defined under carbocyclic aryl above, advantageously optionally substituted benzyl, e.g. benzyl substituted or phenyl lay lower alkyl.

Heterocyclic aryl-lower alkyl represents preferably straight chain or branched heterocyclic aryl-C<sub>1-4</sub>-alkyl in which heterocyclic aryl has meaning as defined above, e.g. 2-, 3- or 4-pyridylmethyl or (2, 3- or 4-pyridyl)-(ethyl, propyl or butyl); or 2- or 3-thienylmethyl or (2- or 3-thienyl)-(ethyl). propyl or butyl); 2-, 3- or 4-quinolinylmethyl or (2-, 3- or 4-quinolinyl)-(ethyl, propyl or butyl); or 2- or 4-thiazolylmethyl or (2- or 4-thiazolyl)-(ethyl, propyl or butyl).

Cycloalkyl-lower alkyl represents e.g. (cyclopentyl- or cyclohexyl)-(methyl or ethyl).

Biaryl-lower alkyl represents e.g. 4-biphenylyl-(methyl or ethyl).

Acyl as in acyloxy is derived from an organic carboxylic acid, carbonic acid or carbamic acid.

Acyl represents e.g. lower alkanoyl, carbocyclic aryl-lower alkanoyl, lower alkoxycarbonyl, aroyl, dilower alkylaminocarbonyl or di-lower alkylamino-lower alkanoyl. Preferably, acyl is lower alkanoyl.

Lower alkanoyl represents e.g.  $C_{1-7}$ -alkanoyl including formyl, and is preferably  $C_{2-4}$ -alkanoyl such as acetyl or propionyl.

Aroyl represents e.g. benzoyl or benzoyl mono- or di-substituted by one or two radicals selected from lower alkyl, lower alkoxy, halogen, cyano and trifluoromethyl; or 1- or 2-naphthoyl; and also e.g. pyridylcarbonyl.

Lower alkoxycarbonyl represents preferably C<sub>1-4</sub>-alkoxycarbonyl, e.g. ethoxycarbonyl.

Esterified carboxyl is carboxyl derivatized as a pharmaceutically acceptable ester, for example lower alkoxycarbonyl, benzyloxycarbonyl or allyloxycarbonyl.

Amidated carboxyl is carboxyl derivatized as a pharmaceutically acceptable amide, for example aminocarbonyl, mono- or di-lower alkylaminocarbonyl.

Pharmaceutically acceptable salts of the acidic compounds of the invention are salts formed with bases, namely cationic salts such as alkali and alkaline earth metal salts, such as sodium. lithium. potassium, calcium, magnesium, as well as ammonium salts, such as ammonium, trimethylammonium, diethylammonium, and tris-(hydroxymethyl)-methyl-ammonium salts.

Similarly acid addition salts, such as of mineral acids, organic carboxylic and organic sulfonic acids e.g. hydrochloric acid, methanesulfonic acid, maleic acid, are also possible provided a basic group, such as pyridyl, constitutes part of the structure.

The compounds of the invention exhibit valuable pharmacological properties in mammals and are particularly useful as cysteine cathepsin inhibitors.

The cathepsin inhibitory effects of the compound of the invention can be determined in vitro by measuring the inhibition of e.g. recombinant human cathepsins B, K, L and S. The buffer used in the cathepsin B, L and S assays is a 0.1 M pH 5.8 phosphate buffer containing EDTA (1.33 mM), DTT (2.7 mM) and Brij (0.03%).

The in vitro assays are carried out as follows:

#### (a) For cathepsin B:

To a microtiter well is added 100 uL of a 20 uM solution of inhibitor in assay buffer followed by 50 uL of a 6.4 mM solution of Z-Arg-Arg-AMC substrate (Peptides International) in assay buffer. After mixing, 50 uL of a 0.544 nM solution of recombinant human cathepsin B in assay buffer is added to the well, yielding a final inhibitor concentration of 10 uM. Enzyme activity is determined by measuring fluorescence of the liberated aminomethylcoumarin at 440 nM using 380 nM excitation, at 20 minutes. % Enzyme inhibition is determined by comparison of this activity to that of a solution containing no inhibitor. Compounds are subsequently subjected to a dose response curve analysis to determine IC<sub>50</sub> values.

### (b) For cathepsin K:

The assay is performed in 96 well microtiter plates at ambient temperature using recombinant human cathepsin K. Inhibition of cathepsin K is assayed at a constant enzyme (0.16 nM) and substrate concentration (54 mM Z-Phe-Arg-MCA - Peptide Institute Inc. Osaka, Japan) in 100 mM sodium phosphate buffer, pH 7.0, containing 2 mM dithiothreitol, 20 mM Tween 80 and 1 mM EDTA. Cathepsin K is preincubated with the inhibitors for 30 min, and the reaction is initiated by the addition of substrate. After 30 min incubation the reaction is stopped by the addition of E-64 (2 mM), and fluorescence intensity is read on a multi-well plate reader at excitation and emission wavelengths of 360 and 460 nm. respectively.

#### (c) For cathepsin L:

Recombinant human cathepsin L is activated prior to use in this assay: To 500 uL of a 510 nM solution of cathepsin L in a 50 mM pH 5.0 acetate buffer containing 1 mM EDTA, 3 mM DTT and 150 mM NaCl is added 10 uL of a 625 uM solution of dextran sulfate (ave. mw = 8000), and the resulting solution is incubated on ice for 30 min. 4 uL of this solution is then diluted into 46 uL assay buffer, yielding a 40 nM enzyme solution.

To perform the assay, 100 uL of a 20 uM solution of inhibitor in assay buffer is added to a microtiter well. 50 uL of a 20 uM solution of Z-Phe-Arg-AMC (Peptides International) is then added. After mixing, 50 uL of the activated 40 nM solution of recombinant human cathepsin L in assay buffer is then added to the well, yielding a final inhibitor concentration of 10 uM. Enzyme activity is determined by measuring fluorescence of the liberated

aminomethylcoumarin at 440 nM using 380 nM excitation of 20 minutes. % Enzyme inhibition is determined by comparison of this activity to that of a solution containing no inhibitor. Compounds are subsequently subjected to a dose response curve analysis to determine IC<sub>50</sub> values.

### (d) For cathepsin S:

To a microtiter well is added 100 uL of a 20 uM solution of inhibitor is assay buffer. 50 uL of a 700 uM solution of Z-Val-Val-Arg-AMC substrate (Peptides International) is then added. After mixing, 50 uL of a 5.2 nM solution of recombinant human cathepsin S in assay buffer is then added to the well, yielding a final inhibitor concentration of 10 uM. Enzyme activity is determined by measuring fluorescence of the liberated aminomethylcoumarin at 440 nM using 380 nM excitation at 200 minutes. % Enzyme inhibition is determined by comparison of this activity to that of a solution containing no inhibitor. Compounds are subsequently subjected to a dose response curve analysis to determine IC<sub>50</sub> values.

In view of their activity as inhibitors of cysteine cathepsin enzymes, Compounds of the Invention are particularly useful in mammals as agents for treatment and prophylaxis of diseases and medical conditions involving elevated levels of cathepsins. Such diseases include diseases involving infection by organisms such as pneumocystis carinii, trypsanoma cruzi, trypsanoma brucei, crithidia fusiculata, as well as parasitic diseases such as schistosomiasis and malaria, tumours (tumour invasion and tumour metastasis), and other diseases such as metachromatic leukodystrophy, muscular dystrophy, amytrophy and similar diseases.

Cathepsins, in particular K, have been implicated in diseases of excessive bone loss, and thus the Compounds of the Invention may be used for treatment and prophylaxis of such diseases, including osteoporosis, gingival diseases such as gingivitis and periodontitis, Paget's disease, hypercalcemia of malignancy, e.g. tumour-induced hypercalcemia and metabolic bone disease. Also the Compounds of the Invention may be use for treatment or prophylaxis of diseases of excessive cartilage or matrix degradation, including osteoarthritis and rheumatoid arthritis as well as certain neoplastic diseases involving expression of high levels of proteolytic enzymes and matrix degradation.

wherein R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub> and R<sub>5</sub> have meaning as defined hereinabove with an acid corresponding to the group R-[L]<sub>x</sub>-X<sub>1</sub>- or with a reactive derivative thereof; and in the above processes, if required, temporarily protecting any interfering reactive groups and then isolating the resulting compound of the invention; and, if desired, converting any resulting compound into another compound of the invention; and/or if desired, converting a resulting compound into a salt or a resulting salt into the free acid or base or into another salt.

Appropriate protecting groups are used for starting compounds and intermediates, for instance as hereinafter described in the Examples.

The conversion of primary amides of formula V to the nitriles of formula I, according to process (a), can be carried out according to methods well known in the art for the dehydration of a primary amide to a nitrile, e.g. with thionyl chloride in the presence of a base. A preferred procedure involves the treatment with oxalyl chloride and pyridine in DMF at or below room temperature as illustrated in the examples.

The starting materials of formula VI can be prepared by condensing an amino acid amide of formula IX

wherein R<sub>4</sub>, and R<sub>5</sub> have meaning as defined above with an acid of the formula VIII, in protected form as appropriate.

The condensation can be carried out according to methods well-known in the art, e.g. by reacting a mixed anhydride or an acyl halide of the acid of formula VIII e.g. the acid chloride, with an amino acid amide of formula IX, in an inert solvent such as methylene chloride, in the presence of a base, such as an amine like triethylamine or pyridine.

The acylation of an acid of formula VIII with an amino acid amide of formula IX can also be carried out in the presence of a condensing agent such as N-(3-dimethylaminopropyl)-N'-ethyl-carbodiimide, optionally in the presence of e.g. hydroxybenzotriazole or 1-hydroxy-7-azabenzotriazole, and a base such as N-methylmorpholine.

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The amino acid amides of formula IX are either known or can be prepared according to methodology known in the art and illustrated herein.

Alternative procedures and conditions may be used; for instance as described in the Examples.

Compounds of the invention are either obtained in the free form, or as a salt thereof if salt forming groups are present.

Acidic Compounds of the Invention may be converted into metal salts with pharmaceutically acceptable bases, e.g. an aqueous alkali metal hydroxide, advantageously in the presence of an ethereal or alcoholic solvent, such as a lower alkanol. Resulting salts may be converted into the free compounds by treatment with acids. These or other salts can also be used for purification of the compounds obtained. Ammonium salts are obtained by reaction with the appropriate amine. e.g. diethylamine, and the like.

Compounds of the Invention having basic groups can be converted into acid addition salts, especially pharmaceutically acceptable salts. These are formed, for example, with inorganic acids, such as mineral acids, for example sulfuric acid, a phosphoric or hydrohalic acid, or with organic carboxylic acids, such as (C<sub>1</sub>-C<sub>4</sub>)alkanecarboxylic acids which, for example, are unsubstituted or substituted by halogen, for example acetic acid, such as saturated or unsaturated dicarboxylic acids, for example oxalic, succinic, maleic or fumaric acid, such as hydroxycarboxylic acids, for example glycolic, lactic, malic, tartaric or citric acid, such as amino acids, for example aspartic or glutamic acid, or with organic sulfonic acids, such as (C<sub>1</sub>-C<sub>4</sub>)-alkylsulfonic acids (for example methanesulfonic acid) or arylsulfonic acids which are unsubstituted or substituted (for example by halogen).

Preferred are salts formed with hydrochloric acid, methanesulfonic acid and maleic acid.

In view of the close relationship between the free compounds and the compounds in the form of their salts, whenever a compound is referred to in this context, a corresponding salt is also intended, provided such is possible or appropriate under the circumstances.

The compounds, including their salts, can also be obtained in the form of their hydrates, or include other solvents used for their crystallization.

The pharmaceutical compositions according to the invention are those suitable for enteral, such as oral or rectal, transdermal, topical, and parenteral administration to mammals, including man, to inhibit cathepsin activity, and for the treatment of cathepsin dependent disorders, in particular inflammation, osteoporosis, rheumatoid arthritis and osteoarthritis, and comprise an effective amount

of a pharmacologically active compound of the invention, alone or in combination, with one or more pharmaceutically acceptable carriers.

More particularly, the pharmaceutical compositions comprise an effective cathepsin inhibiting amount of a Compound of the Invention.

The pharmacologically active Compounds of the Invention are useful in the manufacture of pharmaceutical compositions comprising an effective amount thereof in conjunction or admixture with excipients or carriers suitable for either enteral or parenteral application. Preferred are tablets and gelatin capsules comprising the active ingredient together with a) diluents, e.g. lactose, dextrose, sucrose, mannitol, sorbitol, cellulose and/or glycine; b) lubricants, e.g. silica, talcum, stearic acid, its magnesium or calcium salt and/or polyethyleneglycol; for tablets also c) binders e.g. magnesium aluminum silicate, starch paste, gelatin, tragacanth, methylcellulose, sodium carboxymethylcellulose and or polyvinylpyrrolidone; if desired d) disintegrants, e.g. starches, agar, alginic acid or its sodium salt, or effervescent mixtures; and/or e) absorbents, colorants, flavors and sweeteners. Injectable compositions are preferably aqueous isotonic solutions or suspensions, and suppositories are advantageously prepared from fatty emulsions or suspensions. Said compositions may be sterilized and/or contain adjuvants, such as preserving, stabilizing, wetting or emulsifying agents, solution promoters, salts for regulating the osmotic pressure and/or buffers. In addition, they may also contain other therapeutically valuable substances. Said compositions are prepared according to conventional mixing, granulating or coating methods, respectively, and contain about 0.1 to 75%, preferably about 1 to 50%, of the active ingredient.

Tablets may be either film coated or enteric coated according to methods known in the art.

Suitable formulations for transdermal application include an effective amount of a compound of the invention with carrier. Advantageous carriers include absorbable pharmacologically acceptable solvents to assist passage through the skin of the host. For example, transdermal devices are in the form of a bandage comprising a backing member, a reservoir containing the compound optionally with carriers, optionally a rate controlling barrier to deliver the compound of the skin of the host at a controlled and predetermined rate over a prolonged period of time, and means to secure the device to the skin. Matrix transdermal formulations may also be used.

Suitable formulations for topical application, e.g. to the skin and eyes, are preferably aqueous solutions, ointments, creams or gels well-known in the art. Such may contain solubilizers, stabilizers, tonicity enhancing agents, buffers and preservatives.

The pharmaceutical formulations contain an effective cathepsin inhibiting amount of a Compound of the Invention as defined above, either alone or in combination with another therapeutic agent.

In conjunction with another active ingredient, a Compound of the Invention may be administered either simultaneously, before or after the other active ingredient, either separately by the same or different route of administration or together in the same pharmaceutical formulation. The dosage of active compound administered is dependent on the species of warm-blooded animal (mammal), the body weight, age and individual condition, and on the form of administration. A unit dosage for oral administration to a mammal of about 50 to 70 kg may contain between about 5 and 500 mg of the active ingredient.

The present invention also relates to methods of using Compounds of the Invention and their pharmaceutically acceptable salts, or pharmaceutical compositions thereof, in mammals for inhibiting cathepsins, such as cathepsin B, K, L and/or S, and for the treatment of cathepsin dependent conditions, such as cathepsin B, K, L and/or S dependent conditions, described herein, e.g. inflammation, osteoporosis, rheumatoid arthritis and osteoarthritis.

Particularly the present invention relates to a method of selectively inhibiting cathepsin activity in a mammal which comprises administering to a mammal in need thereof an effective cathepsin inhibiting amount of a Compound of the Invention.

More specifically such relates to a method of treating rheumatoid arthritis, osteoarthritis, and inflammation (and other diseases as identified above) in mammals comprises administering to a mammal in need thereof a correspondingly effective amount of a Compound of the Invention.

The following examples are intended to illustrate the invention and are not to be construed as being limitations thereon. Temperatures are given in degrees Centrigrade. If not mentioned otherwise, all evaporations are performed under reduced pressure, preferably between about 15 and 100 mm Hg (= 20-133 mbar). The structure of final products, intermediates and starting materials is confirmed by standard analytical methods, e.g. microanalysis and spectroscopic characteristics (e.g. MS, IR, NMR). Abbreviations used are those conventional in the art.

#### **EXAMPLES**

## Example 1: Preparation of Indol-4-yl-C(O)-Leu-Gly(CN) of formula X

### A. Fmoc-Leu-Gly(CN)

[l-(Cyanomethyl-carbamoyl)-3-methyl-butyl]-carbamic acid 9.H.-fluoren-9-yl methyl ester

Fmoc-Leucine (0.27mmol) and aminoacetonitrile hydrochloride (32.4mmol) are dissolved in dimethylformamide (300ml) and cooled with ice-salt. HOBt (32.4mmol) and WSCD (32.4mmol) are added, and the reaction mixture is stirred at 4 - 25°C over night. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with saturated sodium bicarbonate, lN hydrochloric acid and brine, dried over magnesium sulfate and the solvent is evaporated.

Chromatography on silica gel using n-hexane/ethyl acetate=1/1 (v/v) gives the product in 90% yield. mp.173-175°C, Rf=0.68 (chloroform:methanol:acetic acid=90: 10: 1).

#### B. H-Leu-Gly(CN)

2-Amino-4-methyl-pentanoic acid cyanomethyl-amide

Fmoc-Leu-Gly(CN) (18mmol) is dissolved in 20% piperidine in dimethylformamide (36ml). The reaction mixture is stirred at room temperature for 60min. After evaporation of the solvent and chromatography on silica gel using n-hexane, n-hexane/ethyl acetate=1/1 and 10% methanol in chloroform, the product is obtained in 93% yield.

oil, Rf=0.73 (n-propanol:water:ethyl acetate:ammonia=5:1:2:1).

#### C. Indol-5-yl-C(O)-Leu-Gly(CN)

Indol-5-ylcarboxylic acid (l.Oeq.) and H-Leu-Gly(CN) (1.2eq.) are dissolved in dimethylformamide and cooled with ice-salt. HOBt (1.2eq.) and WSCD (1.2eq.) are added and the reaction mixture is stirred at 4 - 25°C over night. After ethyl acetate is added to the reaction mixture, the organic layer is washed with saturated sodium bicarbonate, lN hydrochloric acid and brine, dried over magnesium sulfate and evaporated. Chromatography on silica gel gives the title product in 70%

yield.

mp. 201-204°C, Rf=0.39 (n-hexane:AcOEt=1:2)

Example 2 5-Amino-quinoline-2-carboxylic acid [1-(cyanomethyl-carbamoyl)
-3-methyl-butyl]-amide

5-Nitro-quinoline-2-carboxylic acid [1 -(cyanomethyl-carbamoyl)-3-methyl-butyl] -amide (0.35mmol) is dissolved in tetrahydrofuran (l0ml) and methanol (l0ml) at room temperature.  $Na_2S_2O_4$  aq \* (7mmol) is added to the solution, and the reaction mixture is heated at reflux for 90min. The crude product is isolated by filtration and purified by chromatography on silica gel using 2% methanol in chloroform. The product is obtained in 33% yield. mp.l90-194°C, Rf=0.60 (n-hexane:ethyl acetate=1:5). \*A.S.Kende et al., Tetrahedron Lett., 25, 923-926, (1984).

## Example 3 p -Acetamidomethylbenzoyl-Leu-Gly(CN)

p-Aminomethylbenzoyl-Leu-Gly(CN) (see Example 14 below)(0.33mmol) and acetic acid (3.3mmol) are dissolved in dimethylformamide (l0ml) and cooled in an ice bath. HOBt (0.4mmol) and WSCD (0.4mmol) are added and the reaction mixture is stirred at 4 - 25°C over night. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with saturated sodium bicarbonate, lN hydrochloric acid and brine, dried over magnesium sulfate and evaporated. Diethylether is added to the residue to give a precipitate, which is collected by filtration and precipitated again from ethyl acetate with diethylether to give the product in 32% yield. mp.176-184.5°C, Rf=0.24 (chloroform:methanol =9:1).

By repeating the procedures described in the above Examples using appropriate starting materials and conditions the following compounds of formula XI are obtained as identified below in Table 1.

Example No.		Rx	mp. (°C)	Rf (solvent)
20	\$			0.47 (n-hexane:AcOEt=1:1)
21	CH.O	CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub>	122-126	0.18 (CH <sub>2</sub> Cl <sub>2</sub> :MeOH=9:1)
22	НО	CH <sub>2</sub> CH <sub>2</sub>	oil	0.17 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH/NH <sub>3</sub> =9:1)
23	Z	CH <sub>2</sub>	248-250	0.35 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)
24	o.	N CH <sub>2</sub>	136-138	0.21 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=95:5)
25		CH <sub>2</sub>	225-227	0.10 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)
26	CH <sub>3</sub> O	CH <sub>2</sub> CH <sub>2</sub> -CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	97-99	0.41 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)
27	N	CH <sub>2</sub>	164-168	0.27 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)
28	0	ON CH <sub>2</sub>	114-116	0.16 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=95:5)
29		CH <sub>2</sub>	<70	0.16 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)

Example No.	Rx	mp. (°C)	Rf	(solvent)
30	CH <sub>3</sub> O-CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	89-91	0.19 (CH <sub>2</sub>	Cl <sub>2</sub> /MeOH=9:1)

Example 31 Indole-2-carboxylic acid {1-[(cyano-dimethyl-methyl)-carbamoyl] -cyclohexyl}-amide

## A. Fmoc-1-aminocyclohexane carboxylic acid

The title compound is prepared from 1-cyclohexane carboxylic acid (7mmol), Fmoc-CI (7.7mmol) and NaOH (14mmol) in the usual manner in 18 % yield. Rf=0.17 (n-hexane:ethyl acetate=1:2).

#### B. <u>Boc-2-Aminoisobutyric acid amide</u>

28% aqueous ammonia (66mmol) is added to the mixed anhydride (prepared from 22mmol of Boc-2-aminobutyric acid and 22mmol of iso-butylcholoroformate by customary procedures) at -20°C. The reaction mixture is stirred at 4 - 25°C overnight. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with saturated sodium bicarbonate, IN hydrochloric acid and brine, dried over magnesium sulfate and evaporated. The crude product is purified by chromatography on silica gel using n-hexane/ethyl acetate=1/1 and n-hexane/ethyl acetate=1/2, to give the product in 31 % yield.

mp. 168-177.5°C, Rf=0.41 (chloroform:methanol=9: 1).

#### C. 2-Aminobutyric acid amide hydrochloride

Boc-2-Aminoisobutyric acid amide is dissolved in 4N hydrochloride in dioxane. The reaction mixture is stirred at room temperature for 60min. Diethylether is added to the solution to give a white precipitate, which is collected in 91 % yield by filtration. The crude product is used for the next coupling without further purification.

Rf=0.28 (n-PrOH:H<sub>2</sub>0:ethyl acetate:NH3=5: 1:2: 1).

# D. Fmoc-1-Amino-cyclohexanecarboxylic acid (1-carbamoyl-1-methyl-ethyl) -amide

Fmoc-l-aminocyclohexane carboxylic acid (2.2mmol) and 2-aminobutyric acid amide hydrochloride (2.2mmol) are dissolved in dimethylformamide (30ml) and cooled with ice-salt. HOBt (2.6mmol) and

WSCD (2.6mmol) are added and the reaction mixture is stirred at 4 - 25°C over night. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with saturated sodium bicarbonate, IN hydrochloric acid and brine, dried over magnesium sulfate and evaporated. The crude product is purified by chromatography on silica gel using n-hexane/ethyl acetate=1/4 and n-hexane/ethyl acetate=1/6, to give the product in quantitative yield. mp.177.5-178.5°C, Rf=0.24 (n-hexane:ethyl acetate=1:5)

E. Fmoc-l-Amino-cyclohexanecarboxylic acid (cyano-dimethyl-methyl)

-amide

Thionyl chloride (2.6mmol) is added to the solution of Fmoc-1-amino-cyclohexanecarboxylic acid (1-carbamoyl-1-methyl-ethyl)-amide (0.86mmol) in dimethylformamide (10ml) at 4°C. The reaction mixture is stirred at 4°C for 2h., ethyl acetate and saturated sodium bicarbonate solution are added and the organic layer is washed with brine, dried over magnesium sulfate and evaporated. The crude product is purified by chromatography on silica gel using n-hexane/ethyl acetate=3/1, to give the product in quantitative yield.

Rf=0.57 (n-hexane:ethyl acetate=1:1).

F. 1-Amino-cyclohexanecarboxylic acid (cyano-dimethyl-methyl)-amide
Fmoc-1-Amino-cyclohexanecarboxylic acid (cyano-dimethyl-methyl)-amide (2.1 mmol) is dissolved in 20% piperidin in dimethylformamide (6.3ml). The reaction mixture is stirred at room temperature for 60min. After evaporation of the solvent, the crude product is purified by chormatography on silica gel using n-hexane, n-hexane/ethyl acetate=I/I and 10% methanol in chloroform, to give the product in 31 % yield. oil,

Rf=0.84 (n-propanol:water:ethyl acetate:ammonia=5:1:2:1)

G. Indole-2-carboxylic acid {1-[(cyano-dimethyl-methyl)-carbamoyl] -cyclohexyl}-amide

2-Indole carboxylic acid (0.5lmmol) and l-amino-cyclohexanecarboxylic acid (cyano-dimethyl-methyl)-amide (0.61mmol) are dissolved in dimethylformamide (15ml) and cooled in an ice bath. HOBt (0.61mmol) and WSCD.HCI (0.61mmol) are added and the reaction mixture is stirred at 4 - 25°C over night. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with saturated sodium bicarbonate, 1N hydrochloric acid and brine. dried over magnesium sulfate and evaporated. The crude product is purified by chromatography on silica using n-hexane/ethyl acetate=4/1 and n-hexane/ethyl acetate=2/1, to give the product in 71% yield.

mp.200-202°C, Rf=0.55 (n-hexane:ethyl acetate= 1: 1)

- Example 32 Synthesis of Naphthalene-2-carboxylic acid [1-(cyanomethyl-carbamoyl) -2-methyl-butyl]-amide
- A. 2-tert-Butyloxycarbonylamino-3-methyl-pentanoic acid cyanomethyl
  -amide

N-Tertbutyloxycarbonyl-isoleucine semihydrate (3g, 12.5mmol), HOBt (3, 71 g, 27.5 mmol, 2.2 eq.) and aminoacetonitrile hydrochloride (1.27g, 13.7mmol, l.leq.) are dissolved in dimethylformamide (36ml) and WSCD (2.5ml, 13.7mmol, l.leq.) is added. After stiring for 1 hour at rt, 4% sodium bicarbonate solution is added and the mixture is extracted with ethyl acetate. The organic layer is washed with sodium bicarbonate and dilute hydrochloric acid, dried over magnesium sulfate and evaporated, to give the product in quantitative yield.

mp. 125-133.5°C, Rf= 0.44 (hexanes:ethyl acetate = 1: 1)

B. 2-Amino-3-methyl-pentanoic acid cyanomethyl-amide hydrochloride
2-tert-Butyloxycarbonylamino-3-methyl-pentanoic acid cyanomethyl-amide (2g, 7.4 mmol) is
dissolved in 4N hydrochloride in dioxane (l0ml). After l5min. at rt the solvent is evaporated to give
the product in quantitative yield. The crude product is used for the next step without further
purification.

Rf (free amine) = 0.33 (ethyl acetate:methanol = 10:1)

- C. Naphthalene-2-carboxylic acid [1-(cyanomethyl-carbamoyl)-2-methyl -butyl]-amide
- 2-Naphthoylchloride (255mg, 1.34mmol, 1.1 eq.) is added to the solution of 2-amino-3-methyl-pentanoic acid cyanomethyl-amide hydrochloride (250mg, 1.22mmmo) and triethylamine (0.42ml, 3.04mmol, 2.5 eq.) in 5 ml dichloromethane. After 1 hour at rt 1 N hydrochloric acid is added and the reaction mixture is extracted with ethyl acetate. The organic layer is washed with saturated sodium bicarbonate solution, dried over magnesium sulfate and evaporated. Chromatography on silica gel (hexane/ethyl acetate 10/1 to 5/1, followed by ethyl acetate) gives the product in 97% yield (381mg).

mp. 203.5-207°C, Rf= 0.44 (hexanes:ethyl acetate = 1: 1).

Example 33 Synthesis of Naphthalene-2-carboxylic acid [1-(1-cyano-3-methyl-butyl]-amide

## A. N-(Naphthalene-2-carbonyl)-isoleucine methylester

L-isoleucine methylester hydrochloride (2.0g, 11.0mmol) and triethylamine (3.lml, 22.0mmol, 2eq.) are dissolved in dichloromethane (40ml). The solution is cooled in an icebath and 2-naphthoylchloride (2.lg, 11.0mmol, leq.) is added. The reaction mixture is allowed to warm up to rt and after 1 hour 1N hydrochloric acid is added. The mixture is extracted with ethyl acetate, the organic layer is washed with saturated sodium bicarbonate solution, dried over magnesium sulfate and evaporated to give the product in 98% yield.

Rf= 0.50 (hexanes:ethyl acetate = 2: 1)

## B. <u>N-(Naphthalene-2-carbonyl)-isoleucine</u>

N-(Naphthalene-2-carbonyl)-isoleucine methylester (3.14g, 10.5mmol) is stlrred in a mlxture of methanol (35ml) and 1 N aqueous sodium hydroxide (16.8ml, 1.6 eq.). After 3 hours at rt the mixture is heated for 1 hour at 40°C. 1 N hydrochloric acid and brine is added and the mixture is extracted with ethyl acetate. The organic layer is dried over magnesium sulfate and evaporated to give the product in quantitative yield (partly epimerized).

Rf= 0.32 (hexane:ethyl acetate = 1:2)

## C. (S)-l-Cyano-3-methyl-butylamine hydrochloride

(S)-N-tert-Butyloxycarbonyl-1-cyano-3-methyl-butylamine (CAS 115654-59-6) (3.7g, 17.4mmol) is dissolved in 4N hydrogenchloride in dioxane (20ml). After 15 minutes at rt the solvent is evaporated, the residue is taken up in diethylether, the solid is filtered and dried in vacuum to give the product in 81 % yield.

Rf (free amine) = 0.34 (hexane:ethyl acetate = 1:1)

# D. Naphthalene-2-carboxylic acid [1-(1-cyano-3-methyl-butylcarbamoyl) -2-methyl-butyl]-amide

N-(Naphthalene-2-carbonyl)-isoleucine (250mg, 0.87mmol), (S)-1-cyano-3-methyl-butylamine (143mg, 0.96mmol, 1.leq.) and HOBt (260mg, 1.93mmol, 2.2eq.) are dissoved in dimethylformamide (5ml) and WSCD (0.17ml, 0.96mmol, 1. leq.) is added. After stirring for 1 hour at rt, 4% sodium bicarbonate solution is added and the mixture is extracted with ethyl acetate. The organic layer is washed with sodium bicarbonate and dilute hydrochloric acid, dried over magnesium sulfate and evaporated. Chromatography on silica gel (hexane/ethyl acetate 2/1) gives the product in 68% yield (mixture of epimers).

Rf= 0.43 (hexanes:ethyl acetate = 2: 1)

Example 34 Synthesis of Naphthalene-2-carboxylic acid [1 -(1 -cyano-3-methyl -butylcarbamoyl)-3-methyl-butyl]-amide

#### A. N-(Naphthalene-2-carbonyl)-leucine

The title compound is prepared analogously is prepared similar to N-(Naphthalene-2 -carbonyl)-isoleucine (see above) in 98% yield, starting from leucine methylester.

Rf= 0.34 (hexanes:ethyl acetate = 1:1)

# B. Naphthalene-2-carboxylic acid [1 -(1 -cyano-3-methyl-butylcarbamoyl)-3 -methyl-butyl]-amide

N-(Naphthalene-2-carbonyl)-leucine (250mg, 0.88mmol), (S)-1-cyano-3-methyl-butylamine (143mg, 0.96mmol, 1.1 eq.) and HOBt (260mg, 1.93mmol, 2.2eq.) are dissovled in dimethylformamide (5ml) and WSCD (0.18ml, 0.97mmol, l.leq.) is added. After stiring for 1

hour at rt, 4% sodium bicarbonate solution is added and the mixture is extracted with ethyl acetate.

The organic layer is washed with sodium bicarbonate and dilute hydrochloric acid, dried over magnesium sulfate and evaporated. Chromatography on silica gel (hexane/ethyl acetate 2/1) gives the product in 79% yield (mixture of epimers).

Rf= 0.44 (hexane:ethyl acetate = 2:1)

# Example 35 Naphthalene-2-carboxylic acid { 1-[1-cyano-2-(IH-indol-3-yl) -ethylcarbamoyl]-3-methyl-butyl}-amide

The title compound is prepared analogously to the compound of Example 22.

N-(Naphthalene-2-carbonyl)-leucine and 1-cyano-2-(lH-indol-3-yl)-ethylamine (CAS 169545-97-5) are reacted by the same procedure as for Naphthalene-2-carboxylic acid

[l-(l-cyano-3-methyl-butylcarbamoyl)-3-methyl-butyl]-amide, to give the product in 36% yield after chromatography on silica gel (hexane/ethyl acetate 1/1) (mixture of epimers).

Rf= 0.59 (hexane:ethyl acetate = 1: 1)

# Example 36 Naphthalene-2-carboxylic acid[1-(1-cyano-1-methyl-ethylcarbamoyl)-3-methyl-butyl]-amide

A. <u>N-tert-Butyloxycarbonyl-1-cyano-1-methyl-ethylamine</u>

Boc-2-aminoisobutyric acid amide(4.58g, 22.6 mmol) and triethylamine(7 ml, 50mmol, 2.2eq.) are dissolved in THF(100ml) and trifluoroacetic acid anhydride(3.5 ml, 25mmol, 1.1 eq.) is added at 0. The reaction mixture is stirred at 0° for 1 hour. The mixture is concentrated and water is added. The organic layer is extracted with ethyl acetate, washed with brine, dried over sodium sulfate and evaporated. The crude product is purified by chromatography on silica gel using n-hexane/ethyl acetate=20/1, 10/1, 5/1 and 1/1 to give the product in 74 % yield.

Rf=0.45(n-hexane/ethyl acetate=3/1)

B. <u>1-Cyano-1-methyl-ethylamine hydrochloride</u>

N-tert-Butyloxycarbonyl-1-cyano-1-methyl-ethylamine (3.09 g, 16.8 mmol) is dissolved in dioxane (15 ml) and 4N hydrochloric acid-dioxane (25 ml) is added at 0°. The reaction mixture is stirred at 0° for 1.5 hours, then at rt for 1 hour. The mixture is concentrated and diethyl ether is added. The resulting white precipitate is washed with diethyl ether and dried to give the product in 83 % yield. The crude product is used for the next coupling without further purification . Rf=0.66(n-PrOH/H<sub>2</sub>O/ethyl acetate/NH<sub>3</sub>=5/1/2/1)

C. Naphthalene-2-carboxylic acid[1-(1-cyano-1-methyl-ethylcarbamoyl)-3-methyl-butyl]-amide

N-(Naphthalene-2-carbonyl)-leucine (279 mg, 0.98 mmol), 1-cyano-1-methyl-ethylamine hydrochloride (137 mg, 1.14 mmol, 1.2 eq.) and HOBt (297 mg, 2.20 mmol, 2.2 eq.) are dissolved in dimethylformamide(5 ml) and WSCD (0.2 ml, 1.09 mmol, 1.1 eq.) is added at -10°. After stirring for 1.5 hours at -10°, 5% sodium bicarbonate solution is added and the mixture is extracted with ethyl acetate. The organic layer is washed with brine, dried over sodium sulfate and evaporated. Chromatography on silica gel (n-hexane/ethyl acetate=20/1, 10/1, 5/1, 3/1 and 1/1) gives the product in 8.7% yield (mixture of enantiomers).

Rf=0.54(n-hexane/ethyl acetate=1/1)

Example 37 Naphthalene-2-carboxylic acid[1-(1-cyano-4-phenyl-propylcarbamoyl)-3-methyl-butyl]-amide

A. <u>Boc-2-Amino-4-phenyl-butyric acid amide Boc-Hph-CONH2</u>

28 % aqueous ammonia(34 mmol) is added to the mixed anhydride (prepared from 16,8 mmol of Boc-homophenylalanine and 17.0 mmol of isobutylchloroformate as usual) at -10. The reaction mixture is stirred at rt for 4.5 hours. The mixture is concentrated, washed with saturated sodium bicarbonate, 1N hydrochloric acid and brine, dried over sodium sulfate and evaporated to give the product in quantitative yield. The crude product is used for the next reaction without further purification.

Rf=0.60(chloroform/mathanol=10/1)

Thereafter the title compound

is prepared analogously as in steps A, B and C of Example 36 Rf=0.81(n-hexane/ethyl acetate=1/1)

Example 38 Naphthalene-2-carboxylic acid[1-(1-cyano-4-phenyl-propylcarbamoyl)-cyclohexyl]-amide

A. Naphthalene-2-carboxylic acid[(1-methoxycarbonyl)-cyclohexyl]-amide

1-Amino-cyclohexanecarboxylic acid methyl ester hydrochloride (1 g, 5.2 mmol) and triethylamine (1.44 ml, 10.3 mmol, 2 eq.) are dissolved in dichloromethane (15 ml) and 2-naphthoyl chloride (1g, 5.2 mmol, 1 eq.) is added at 0°. The reaction mixture is stirred at 0° - 25° for 2 hours and 1N hydrochloric acid is added. The mixture is extracted with ethyl acetate, the organic layer is washed with saturated sodium bicarbonate solution, dried over sodium sulfate and evaporated. Chromatography on silica gel (n-hexane/ethyl acetate=10/1, 5/1, 3/1 and 1/1) gives the product in 93 % yield.

Rf=0.30(n-hexane/ethyl acetate=3/1)

B. N-(2-Naphthoyl)-1-amino-cyclohexanecarboxylic acid

Starting from Naphthalene-2-carboxylic acid[(1-methoxycarbonyl)-cyclohexyl]-amide, the product is prepared analogously to N-(naphthalene-2-carbonyl)-isoleucine in quantitative yield. It is used for the next coupling without further purification.

Rf=0.60(chloroform/methanol=10/1)

C. Naphthalene-2-carboxylic acid[1-(1-cyano-4-phenyl-propylcarbamoyl)-cyclohexyl]-amide

N-(2-Naphthoyl)-1-amino-cyclohexanecarboxylic acid (67 mg, 0.22 mmol), 1-cyano-3-phenyl-propylamine hydrochloride (47 mg, 0.24 mmol, 1.1 eq.) and HOAt (65 mg, 0.48 mmol, 2.2eq.) are dissolved in dimethylformamide (2 ml) and WSCD (0.044 ml, 0.24 mmol, 1.1 eq.) is added at -10 $^{\circ}$  .After stirring at 0 $^{\circ}$  - 25 $^{\circ}$  overnight, 5 % sodium bicarbonate solution is added and the mixture is

extracted with ethyl acetate. The organic layer is washed with brine, dried over sodium sulfate and evaporated. Chromatography on silica gel(chloroform/acetone=200/1 and 100/1) gives the product in 63 % yield.

Rf=0.73(chloroform/acetone=9/1)

Example 39 1.H.-Indole-5-carboxylic acid [1-(cyanomethyl-carbamoyl)-cyclohexyl]-amide

1-Amino-cyclohexancarboxylic acid cyanomethyl-amide (136mg, 0.50mmol), indol-5-carboxylic acid (80mg, 0.50mmol, 1.0 eq.) and HOBt (74mg, 0.55mmol, 1.1eq.) are dissoved in dimethylformamide (5ml) and WSCD (0.10ml, 0.55mmol, 1.1eq.) is added. After stirring for 20 hour at rt, 4% sodium bicarbonate solution is added and the mixture is extraced with ethyl acetate. The organic layer is washed with sodium bicarbonate, dried over magnesium sulfate and evaporated. Chromatography on silica gel (hexanes/ethyl acetate 2/1, then ethyl acetate) gives the product in 20% yield.

Rf = 0.31 (hexanes/ethyl acetate = 3/1)

- Example 40 Synthesis of N-[1-(cyanomethyl-carbamoyl)-cyclohexyl]-4-imidazol-1-ylmethyl-benzamide
- A. <u>Boc-1-aminocyclohexane carboxylic acid</u>

  The title compound is prepared from 1-cyclohexane carboxylic acid (140mmol), Boc<sub>2</sub>O (154mmol) and Na<sub>2</sub>CO<sub>3</sub> (140mmol) in 200 ml dioxane and 100 ml water by conventional methods. Mp. 157-161°C; Rf=0.23 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5)
- Boc-1-amino-cyclohexanecarboxylic acid (1-(cyanomethyl-carbamoyl) -amide
  Boc-1-aminocyclohexane carboxylic acid (40mmol), HOBt (40mmol) and WSCD (42mmol) are
  dissolved in dimethylformamide (75ml) and stirred for 15 min. at RT. 2-aminoacetonitrile
  hydrochloride (40mmol) and triethylamine (40mmol) are suspended in DMF (25ml) and added to the
  reaction mixture which is stirred at 25°C over night. After evaporation of the solvent, the residue is
  extracted with ethyl acetate. The extract is washed with water, 10% citric acid, brine, sodium
  bicarbonate, brine and dried over magnesium sulfate and evaporated. The residue is suspended in
  diethylether and the solid filtered of and dried (vacuum). 7.35g of a white powder with mp.160162°C, Rf=0.28 (n-hexane:ethyl acetate=1:1) is obtained.
- C. <u>1-Amino-cyclohexanecarboxylic acid (1-(cyanomethyl-carbamoyl) -amide</u>
  <u>hydrochloride</u>

HCl in Diethylether (3-4N, 50ml) is added to the solution Boc-1-amino-cyclohexane-carboxylic acid (1-(cyanomethyl-carbamoyl)-amide (33mmol) in THF (50ml) at RT and stirred overnight. The reaction mixture is cooled with an ice bath to 0-4°C and the solid filtered off and washed with diethylether. The white crystals are dried (vacuum). Mp. 205-209°C; Rf=0.45 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1).

- D. N-[1-(cyanomethyl-carbamoyl)-cyclohexyl]-4-bromomethyl-benzamide
  4-Bromomethyl-benzoic acid (2.3mmol) is suspended in CH<sub>2</sub>Cl<sub>2</sub> (7ml) and cooled to 0-5°C.
  Chlorenamine (2.3mmol) is added and the mixture is stirred for 45 min. at 0-5°C.
  1-Amino-cyclohexanecarboxylic acid (1-(cyanomethyl-carbamoyl) -amide hydrochloride (2.3mmol) and N-ethyldiisopropyl-amine (4.6mmol) in CH<sub>2</sub>Cl<sub>2</sub> (7ml) is added at low temperature. The mixture is stirred for 2 hours at 0-5°C and at RT over night. The reaction mixture is diluted with CH<sub>2</sub>Cl<sub>2</sub> (40ml), washed with water and dried over magnesium sulfate and evaporated. The residue was suspended in diethylether and the solid filtered of. The crude product is purified by chromatography on silica using CH<sub>2</sub>Cl<sub>2</sub>/MeOH=97:3. The fractions containing the pure product were collected and evaporated. The residue was suspended in diethylether and the solid filtered of. A white powder with mp.194-196°C, Rf=0.38 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5) is obtained.
- E. N-[1-(cyanomethyl-carbamoyl)-cyclohexyl]-4-imidazol-1-ylmethyl-benzamide
  N-[1-(cyanomethyl-carbamoyl)-cyclohexyl]-4-bromomethyl-benzamide (0.34mmol) is dissolved in
  THF (2ml) and sodium-imidazol (0.41mmol) is added and the reaction mixture stirred at RT over
  night. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is
  washed with water, dried over magnesium sulfate and evaporated. The residue was suspended in
  diethylether and the solid filtered of. The crude product is purified by chromatography on silica using
  CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1. The fractions containing the pure product were collected and evaporated. The
  residue was suspended in diethylether and the solid filtered of. A white powder with mp.194-196°C,
  Rf=0.28 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1) is obtained.

By repeating the procedure described above in Examples 40, using appropriate starting materials and reaction conditions the following compounds of formula XII are obtained as identified below in Table 2.

Example	Rx	Rz	mp. (°C)	Rf (solvent)
No.				MS(M+1)
41		CH CH <sub>3</sub>		0.26 (hexanes/EtOAc = 3/1)
42		Cy Cot,		0.50 (hexanes/EtOAc = 1/1)
43	CH <sub>3</sub> O-CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub>	Н	126-128	0.19 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)
44	N CH2	н	162-165	0.27 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)
45	CH <sub>3</sub> O-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	Н	147-149	0.24 (CH <sub>2</sub> Cl <sub>2</sub> /McOH=9:1)
46		CH, CH CH,		0.26 (hexanes/EtOAc = 3/1)
47	a.	CH <sub>2</sub> ,		0.50 (hexanes/EtOAc = 1/1)
48		Н		0.31 (hexanes/EtOAc = 3/1)
49		CH <sub>2</sub> CH <sub>3</sub>		0.31(n-hexane/EtOAc = 2/1)

50		T	
30		64	0.42 (n-hexane/EtOAc =2/1)
51	CH <sub>3</sub>	ca	0.42 (n-hexane/EtOAc =2/1)
52	CH <sub>3</sub>	66	0.42 (n-hexane/EtOAc =2/1)
53		Н	0.69 (EtOAc)
54		и	0.69 (EtOAc)
55	N	CH <sub>2</sub> CH CH <sub>3</sub> CH <sub>3</sub>	0.58 (n-hexane/EtOAc = 1/1)
56	CH <sub>3</sub>	Н	0.47 (EtOAc)
57		Н	0.72 (EtOAc)
58	CH <sub>3</sub>	ec .	0.73 (EtOAc)

59	F	46		0.66(EtOAc)
60	CH <sub>3</sub>	46		0.66 (EtOAc)
61	CH <sub>3</sub> CH <sub>3</sub>	u		0.67 (EtOAc)
62	CH <sub>2</sub>	CH, CH, ►		0.24 (toluene/acetone 7/3) 436
63		ÇH,	1199-201	446
64	"H"	61	184-185	459
65		ec		0.14(CH <sub>2</sub> Cl <sub>2</sub> /MeOH 10/0.2) 445
66	ec	CH, CH,►		0.54 (petroleum ether/EtOAC 1/1)
67	N= N=	64	154-155	522

Example 68 Synthesis of N-{1-[(Cyano-dimethyl-methyl)-carbamoyl]-3-methyl-butyl}-4-imidazol-1-ylmethyl-benzamide

A. \[ \{ \frac{\{\text{1-[(Cyano-dimethyl-methyl)-carbamoyl]-3-methyl-butyl\}-carbamic acid .tert.-\}{\text{butyl ester}} \]

Boc-Leu-OH (62mmol), HOBt (62mmol) and WSCD (62mmol) are dissolved in dimethylformamide (150ml) and stirred for 15 min. at RT. 2-Amino-2-methyl-propionamide hydrochloride (62mmol) and triethylamine (62mmol) are suspended in DMF (25ml) and added to the reaction mixture which is stirred at 25°C over night. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water, 10% citric acid, brine, sodium bicarbonate, brine and dried over magnesium sulfate and evaporated. The residue is suspended in diethylether and the solid filtered of and dried (vacuum). 14.78g of a white powder with mp.182-184°C, Rf=0.39 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1) is obtained.

B. \[ \left\{ \left[\text{(Cyano-dimethyl-methyl)-carbamoyl}\right]\right\}\ri

{1-[(Cyano-dimethyl-methyl)-carbamoyl]-3-methyl-butyl}-carbamic acid .tert.-butyl ester (47mmol) is dissolved in THF (150ml) and cooled to -10°C. Trifluoroacetic acid anhydride (56mmol) and triethylamine (94mmol) are added at -10°C and the stirred mixture is slowly warmed up to 0°C over 2 hours. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water and dried over magnesium sulfate and evaporated. The residue is suspended in diethylether/ pentane and the solid filtered of and dried (vacuum). 9.93g of a white powder with mp.166-168°C, Rf=0.55 (n-hexane:ethyl acetate=1:1) is obtained.

- C. 2-Amino-4-methyl-pentanoic acid (cyano-dimethyl-methyl)-amide {1-[(Cyano-dimethyl-methyl)-carbamoyl]-3-methyl-butyl}-carbamic acid .tert.-butyl ester (19mmol) is dissolved in ethyl acetate containing HCl (3-4N, water free) and the mixture is stirred at RT overnight. After evaporation of the solvent, the crude product is purified by chromatography on silica using CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1. The fractions containing the pure product were collected and evaporated. 2.3g of a yellowish oil, Rf=0.36 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1) is obtained.
- D. N-{1-[(Cyano-dimethyl-methyl)-carbamoyl]-3-methyl-butyl}-4-bromomethyl-benzamide
- 4-Bromomethylbenzoic acid (4.1mmol), HOBt (4.1mmol) and WSCD.HCI (4.1mmol) are dissolved in dimethylformamide (7ml) and stirred for 10 min. 2-Amino-4-methyl-pentanoic acid (cyano-dimethyl-methyl)-amide (4.1mmol) is added in DMF (3ml) and the reaction mixture is stirred at RT overnight. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is

washed with water, 10% citric acid, brine, sodium bicarbonate, brine and dried over magnesium sulfate and evaporated. The crude product is suspended in diethylether and the solid filtered of and dried (vacuum). A white powder with mp.185-187°C, Rf=0.43 (n-hexane:ethyl acetate=1:1) is obtained.

# E. N-{1-[(Cyano-dimethyl-methyl)-carbamoyl]-3-methyl-butyl}-4-imidazol-1-ylmethyl-benzamide

N- $\{1-[(Cyano-dimethyl-methyl)-carbamoyl]-3-methyl-butyl\}-4-bromomethyl-benzamide (0.18mmol) is dissolved in THF (1ml) and sodium-imidazol (0.41mmol) is added and the reaction mixture stirred at RT over night. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water, dried over magnesium sulfate and evaporated. An oil with Rf=0.44 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH =9:1) is obtained.$ 

By repeating the procedure described above in Examples 68, using appropriate starting materials and conditions the following compounds of formula XIII are obtained as identified below in Table 3.

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 & \underline{\text{Table 3}} \\
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Example	Rx	yield	mp. (°C)	Rf (solvent)
No.		(%)		
		(step B)		
69	CH <sub>3</sub> O-CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	58	135-137	0.29 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)
70	CH <sub>3</sub>	51	160-162	0.16 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)
71	CH <sub>2</sub>	44	186-188	0.23 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)

Example 72 N-[1-(Cyanomethyl-carbamoyl)-3-methyl-butyl]-4-(2-pyrrolidin-1-yl-ethylsulfanyl)-benzamide

### A. 4-(2-Chloroethylsulfanyl)-benzoic acid

4-Mercaptobenzoic acid (65mmol) and 1-Bromo-2-chloro-ethane (71mmol) are dissolved in acetone (120ml) and powdered potassium carbonate (71mmol) is added. The mixture is warmed up to 40°C and stirred for 7 hours. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water and dried over sodium sulfate and evaporated. The crude product is suspended in diethylether and the solid filtered of and dried (vacuum). 7.8g of a white powder with mp.142-144°C, Rf=0.37 (methylenchlorid/methanol=9/1) is obtained.

# B. <u>4-(2-Chloroethylsulfanyl)-benzoyl-Leu-Gly(CN)</u>

4-(2-Chloroethylsulfanyl)-benzoic acid (18.5mmol), HOBt (18.5mmol) and WSCD.HCI (19.4mmol) are dissolved in dimethylformamide (50ml) and stirred for 15 min. H-Leu-Gly((CN) (18.5mmol) is added and the reaction mixture is stirred at RT overnight. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water, 10% citric acid, brine, sodium bicarbonate, brine and dried over magnesium sulfate. After evaporation of the solvent, the crude product is purified by chromatography on silica using CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5. The fractions containing the pure product were collected and evaporated. The product is suspended in diethylether and the solid filtered of and dried (vacuum). 3.15g of a yellowish powder with mp.108-110°C, Rf=0.33 (n-hexane:ethyl acetate=l:1) is obtained.

# C. N-[1-(Cyanomethyl-carbamoyl)-3-methyl-butyl]-4-(2-pyrrolidin-1-yl-ethylsulfanyl)-benzamide

4-(2-Chloroethylsulfanyl)-benzoyl -Leu-Gly(CN) (1.36mmol) is dissolved DMF (2ml) and pyrrolidine (3mmol) is added. The reaction mixture is stirred for 8 hours at RT, then a catalytic amount of potassium iodide is added and again stirred at 50°C overnight. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water and dried over magnesium sulfate and evaporated. The crude material is applied to a column of silica gel. Elution with CH<sub>2</sub>Cl<sub>2</sub>/MeOH=93:7 gives the product in 24% yield (Rf=0.12 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5).

- Example 73 Synthesis of N-[1-(Cyanomethyl-carbamoyl)-3-methyl-butyl]-4-(2-pyrrolidin-1-yl-ethylsulfonyl)-benzamide
- A. 4-(2-Chloroethylsulfonyl)-benzoic acid

4-(2-Chloroethylsulfanyl)-benzoic acid (18.4mmol) is suspended in methylene chloride (60ml) and cooled to -10°C. m-Chloroperbenzoic acid (38.6mmol) are added dropwise in methylene chloride (60ml) and the mixture is stirred for e hours at -10°C. The mixture is diluted methylene chloride (100ml) and a 5% solution of sodium thiosulfate in water is added and the mixture vigorously stirred. The mixture is extracted, washed with water and and dried over sodium sulfate and evaporated. The crude product is recrystallized from ethylacetate and the solid filtered of and dried (vacuum). 2.19g of a pale powder with mp.142-144°C, Rf=0.37 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1) is obtained.

### B. <u>4-(2-Chloroethylsulfonyl)-benzoyl -Leu-Gly(CN)</u>

4-(2-Chloroethylsulfonyl)-benzoic acid (8.8mmol), HOBt (8.8mmol) and WSCD.HCI (8.8mmol) are dissolved in dimethylformamide (25ml) and stirred for 15 min. H-Leu-Gly((CN) (18.5mmol) is added and the reaction mixture is stirred at RT overnight. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water, 10% citric acid, brine, sodium bicarbonate, brine and dried over magnesium sulfate. After evaporation of the solvent, the crude product is purified by chromatography on silica using CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5. The fractions containing the pure product were collected and evaporated. The product is suspended in diethylether and the solid filtered of and dried (vacuum). 0.3g of a white powder, Rf=0.25 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5) is obtained.

# C. N-[1-(Cyanomethyl-carbamoyl)-3-methyl-butyl]-4-(2-pyrrolidin-1-yl-ethylsulfonyl)-benzamide

4-(2-Chloroethylsulfonyl)-benzoyl-Leu-Gly(CN) (0.4mmol) is in pyrrolidine (1ml. The reaction mixture is stirred for 1.5 hours at RT. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water and dried over magnesium sulfate and evaporated. The crude material is applied to a column of silica gel. Elution with CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5 gives the product in 43% yield (Rf=0.30 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5).

Example 74 Synthesis of N-[1-(1-Cyano-3-methyl-butylcarbamoyl)-3-methyl-butyl]-4-imidazol-l-ylmethyl-benzamide

#### A. <u>Boc-Leu-Leu-NH2</u>

Boc-Leu-Leu-OH (Bachem, 43.6mmol) is dissolved in THF (250ml) and N-methylmorpholine (43.6mmol) is added. The mixture is cooled to -20°C and isobutyl chloroformate (43.6mmol) is added dropwise. The mixture is stirred for 10 min. and then a 25% aqueous solution of ammonia

(52.3mmol) is added at -20°C. The mixture is stirred for 3 hours at -20°C to -10°C. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water and dried over magnesium sulfate and evaporated. The crude product is suspended in diethylether and the solid filtered of and dried (vacuum). 14.2g of a white powder with mp.155-156°C, Rf=0.5 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1) is obtained.

#### B. <u>Boc-Leu-Leu(CN)</u>

Boc-Leu-NH2 (41mmol) is suspended in THF (200ml) and triethylamine (83mmol) and trifluoroacetic acid anhydride (41mmol) is added at -5°C. The mixture is stirred for 2 hours at -5°C. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water and dried over magnesium sulfate and evaporated. A yellowish oil with Rf=0.59 (n-hexane:ethyl acetate=2:1) is obtained and deprotected without further purification (step C.).

#### C. H-Leu-Leu(CN)

Boc-Leu-Leu(CN) (41mmol) is dissolved in THF (50ml) and HCl in diethylether (50ml, 3-4N, water-free) is added at RT and the mixture stirred overnight. After evaporation of the solvent the residue is dissolved in methanol and ammonia in methanol (40ml, 3-4N, water-free) is added and the solid material filtered of. The filtrate is evaporated and the crude product is purified by chromatography on silica using CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5. The fractions containing the pure product were collected and evaporated. 5.07g of a yellowish oil with Rf=0.43 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1) is obtained.

# D. <u>4-Bromomethylbenzoyl-Leu-Leu(CN)</u>

4-Bromomethylbenzoic acid (6.67mmol), HOBt (6.67mmol) and WSCD.HCI (7.0mmol) are dissolved in dimethylformamide (15ml) and stirred for 15 min. H-Leu-Leu(CN) (6.67mmol) is added and the reaction mixture is stirred for 2.5 hours at RT. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water, 10% citric acid, brine, sodium bicarbonate, brine and dried over magnesium sulfate. After evaporation of the solvent, the crude product is purified by chromatography on silica using CH<sub>2</sub>Cl<sub>2</sub>/MeOH=97:3. The fractions containing the pure product were collected and evaporated, 1.74g of a yellowish oil with Rf=0.59 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5) is obtained.

# E. N-[1-(1-Cyano-3-methyl-butylcarbamoyl)-3-methyl-butyl]-4-imidazol-1-ylmethyl-benzamide

4-Bromomethylbenzoyl-Leu-Leu(CN) (1.23mmol) is dissolved in THF (5ml) and sodium-imidazol

(1.48mmol) is added and the reaction mixture stirred at RT over night. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with water, dried over magnesium sulfate and evaporated. The crude product is purified by chromatography on silica using CH<sub>2</sub>Cl<sub>2</sub>/MeOH=95:5. The fractions containing the pure product were collected and evaporated. The product is suspended in diethylether and the solid filtered of and dried (vacuum). A white powder with mp.100-103°C, Rf=0.36 (CH<sub>2</sub>Cl<sub>2</sub>/MeOH=9:1) is obtained.

By repeating the procedure described above in Example 74, using appropriate starting materials and conditions the following compounds of formula XIV are obtained as identified below in Table 4.

Table 4

Table 4  $CH_3$  CH  $CH_2$   $CH_3$   $CH_2$   $CH_3$   $CH_2$   $CH_3$   $CH_2$   $CH_3$   $CH_3$   $CH_4$   $CH_3$   $CH_4$   $CH_3$   $CH_4$   $CH_5$   $CH_5$   $CH_5$ 

Example	Rx	yield	mp. (°C)	Rf (solvent)
No.		(%)		
	ı	(step B)		
75	CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	45	-	0.17 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=95:5)
76	CH <sub>3</sub> x HCl	51	-	0.23 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)
77	CH₂ N CH₂	64	-	0.31 (CH <sub>2</sub> Cl <sub>2</sub> /MeOH=9:1)

Example 78 [1-(2-Benzyloxy-1-cyano-ethylcarbamoyl)-3-methyl-butyl]-carbamic acid benzyl ester

A. 3-Benzyloxy-2-(2-benzyloxycarbonylamino-4-methyl-pentanoylamino)-propionic acid

To a suspension of 0.975 g H-Ser(OBzl)-OH in 5 ml of methylene chloride is added 1.52 ml of trimethylchlorosilane. After ten minutes at room temperature 0.98 ml of N,N-diisopropylethyl amine and 1.81g of benzyloxy leucine N-hydroxysuccinimidester is added. The reaction mixture is stirred for 2 hours at room temperature and diluted with ethyl acetate. Ethyl acetate is washed once with saturated  $NH_4Cl$ -solution and once with  $H_2O$ , then dried over sodium sulfate, the solvent is removed and the residue is crystallized from diethylether.

<sup>1</sup>H-NMR (CDCl<sub>3</sub>, ppm): 7.30 (m, 10H), 6.83 (d,1H), 5.32 (d,1H), 5.10 (s, 2H), 4.71 (m,1H), 4.50 (s,2H), 4.28 (m, 1H), 3.92 (m,1H), 3.67 (m,1H), 1.46 -1.79 (m, 3H), 0.92 (d, 6H).

B. <u>[1-(2-Benzyloxy-1-carbamoyl-ethylcarbamoyl)-3-methyl-butyl]-carbamic acid</u> benzyl ester

To a solution of 0.980 g of 3-benzyloxy-2-(2-benzyloxycarbonylamino-4-methyl-pentanoylamino)-propionic acid and 0.25 ml of N-methylmorpholine in 12 ml of tetrahydrofuran 0.3 ml of isobutylchloroformate is added dropwise at -15°C. The reaction mixture is stirred at -15°C for 10 minutes, then 4 ml of aqueous NH<sub>3</sub> (25%) is added dropwise over a time period of 5 minutes. The reaction mixture is stirred for additional 15 minutes and diluted with ethyl acetate. Ethyl acetate is washed once with saturated NH<sub>4</sub>Cl-solution and once with H<sub>2</sub>O, then dried sodium sulfate, the solvent is removed und the residue is triturated with diethylether.

<sup>1</sup>H-NMR (CDCl<sub>3</sub>, ppm): 7.38 (m, 10H), 6.87 (d, 1H), 6.60 (m (br.), 1H), 5.41 (m (br.), 1H), 5.12 (d, 1H), 5.08 (s, 2H), 4.50 (d, 2H), 4.20 - 3.92 (m, 2H), 3.50 (m, 1H), 1.70 - 1.41 (m, 3H), 0.90 (d, 6H).

C. [1-(2-Benzyloxy-1-cyano-ethylcarbamoyl)-3-methyl-butyl]-carbamic acid benzyl

0.3 ml of trifluoroacetic acid anhydride is added dropwise to a solution of 0.9 g of [1-(2-benzyloxy-1-carbamoyl-ethylcarbamoyl)-3-methyl-butyl]-carbamic acid benzyl ester and 0.6 ml of triethylamine in 15 ml of tetrahydrofuran at -5°C. The reaction mixture is stirred at -5°C for 3 hours and then for 12 hours at room temperature. The reaction mixture is then poured into  $H_2O$  and the aqueous layer is extracted three times with ethyl acetate. The combined organic layers are washed once with  $H_2O$  and once with brine, then dried over sodium sulfate, the solvent is removed and the residue is crystallized from diethylether/ hexane. Mp.: 126-127°C.

The following compounds formula XV, as identified in Table 5 below, are prepared analogously to the compound of Example 78.

Example 86 2-[2-(4-Chloro-phenylamino)-acetylamino]-4-methyl-pentanoic acid cyanomethyl-amide

(4-Chloro-phenylamino)-acetic acid (0.5 g) and H-Leu-Gly((CN).HCl (0.55 g) are dissolved in dimethylformamide (4 ml). HOBt (0.44 g), WSCD.HCl (0.54 g), triethylamine (0.37 ml) is added and the reaction mixture is stirred for 18 hours. After evaporation of the solvent, the residue is extracted with ethyl acetate. The extract is washed with 10% citric acid, brine, sodium bicarbonate, brine and dried over magnesium sulfate and evaporated. The crude product is slurried in diethylether and the solid filtered of and dried (vacuum) yielding a white powder with mp.131-134°C.

By repeating the procedure described above in Example 86, using appropriate starting materilas and conditions the following compounds of formula XVI are obtained as identified below in Table 6.

$$\begin{array}{c|c} \underline{Table \ 6} \\ H & O & CH_2 \\ R^* & C & CH & N & C \\ \hline \\ R^* & C & CH & N & C \\ \hline \\ R^* & C & CH_2 & N \\ \hline \\ C & CH_2 & CH_3 \\ \hline \\ C & CH_3 \\ \hline \\ C & CH_3 \\ \hline \\ C & CH_3 \\ \hline \end{array}$$

Example No.	R*	mp. (°C)	Rf (solvent)
87	CI	foam	0.32 (CH2Cl2/MeOH= 95:5)
88	CI NH	110-115	
89	CH <sub>3</sub> N	foam	0.30 (CH2Cl2/MeOH= 95:5)
90	CH <sub>3</sub>	130-133	

Example No.	R*	mp. (°C)	Rf (solvent)
91	, The state of the	amorph	0.42 (CH2Cl2/MeOH= 95:5)
92	D N	131-133	
93	CI LO-	108-110	
94	CI	Resin	0.43 (CH2Cl2/MeOH= 95:5)
95	CI CO-	77-79	
96	CH <sub>3</sub>	Oil	
97	CH <sub>3</sub>	Resin	0.53 (CH2Cl2/MeOH= 95:5)
98	CCO.	foam	0.47 (CH2Cl2/MeOH= 95:5)
99		143-146	

Example No.	R*	mp. (°C)	Rf (solvent)
100		119-121	
101	N)	Resin	0.26 (CH2Cl2/MeOH= 95:5)
102	CCC <sub>s</sub> -	146-149	

By repeating the procedures described in the above Examples using appropriate starting materials and reaction conditions the following compounds of formula XVII are obtained as identified below in Table 7.

RX N C CH XVIII

Rf (solvent)/MS (M+1)	0.44 (hexanes/EtOAc = 1/1)	0.44 (hexanes/EtOAc = 2/1)
mp. (°C)	203.5-207	
Rz	Ħ	HO - CH -
Ry	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	G, CH, CH,
Rx		±
Example No.	103	104

0.52(n-hexane/EtOAc =1/1)	0.45(n-hexane/EtOAc =1/1)	0.30(n-hexane/EtOAc =3/1)	0.40(n-hexane/EtOAc = 2/1)	0.24(n-hexane/EtOAc =4/3)	0.36( <i>n</i> -hexane/EtOAc =2/1)
CH <sub>2</sub>	14	CH, CH,	21	, ₹ , 5,	CH2 CH3 CH3
t)	7	æ	=	2	3
		N CH <sub>3</sub>	N N N N N N N N N N N N N N N N N N N	5	
105	106	107	108	109	110

0-17 (n-hexane/EtOAc = 1/1)	0.27 (n-hexane/EtOAc = 1/1)	0.45 (EtOAc)	0.58 (EtOAc)	0.28 (n-hexane/EtOAc = 1/1)	0.46 (n-hexane/EtOAc = 1/1)
2	z	Ι	Ħ	п	CH, CH,
z	#	H.	¥	z z	T T
CH3 // O		CH <sub>2</sub> N	0=0	N, N, N, E, E, N,	S-S-S-S-S-S-S-S-S-S-S-S-S-S-S-S-S-S-S-
Ξ	112	113	114	115	116

0.41 (n-hexane/EtOAc = 2/1)	0.79 (EtOAc)	0.74 (EtOAc)	0.52 (n-hexane/EtOAc = 1/1)	0.60 (n-hexane/EtOAc = 1/1)	0.60 (EtOAc)	0.54 (n-hexane/EtOAc = 1/1)
**	Ι	=	CH <sub>3</sub> CH <sub>3</sub>	"	I	
7	-F.	3	=	5	T T T T T T T T T T T T T T T T T T T	=
N. F. S.	N N N N N N N N N N N N N N N N N N N		5-0	N N OH3	P - 8	CH, CH, CH,
117	8	.	120	121	77.	123

111 - A C. Dangurd a) 200	0.26 (n-hexane/EtOAc = 1/1)	0.41 (n-hexane/EtOAc = 1/1)	0.43 (n-hexane/EtOAc = 1/1)	433	447	0.65 (toluene/acetone 7/3) 466	470
				151-152	137-138		163-165
Ι		CH <sub>2</sub>	В	A-0, H-0, N-0, N-0, N-0, N-0, N-0, N-0, N-0, N	3	3	э
11		11	в	v	æ		¥
39					OH <sub>s</sub>	CH3 CH3	
124		125	126	127	128	129	130

	<del></del>	<del></del>		*		
447	0.66 (CH <sub>2</sub> Cl <sub>2</sub> /CH <sub>3</sub> OH 10/0.5) 487	466	522	0.46 (CH <sub>2</sub> Cl <sub>2</sub> /CH <sub>3</sub> OH 10/0.5) 477	0.51 (CH <sub>2</sub> Cl <sub>2</sub> /CH <sub>3</sub> OH 10/0.5) 510	0.26 (CH <sub>2</sub> Cl <sub>2</sub> /CH <sub>3</sub> OH 10/0.5) 491
214-215		176-178	106-110			
CH <sub>2</sub> CH <sub>3</sub>	2	н	ŧ	=	3	3
=	2	25	z	2	7	ਬ
OH, SHO	£_8_8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	CH3.CH3 CC, CCH3	F - N N - CH2	± No. 1 No.	F N N-CH <sub>2</sub>	N-CH2
131	132	133	134	135	136	137

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260	548	529	471	522	0.40 (CH <sub>2</sub> Cl <sub>2</sub> /CH <sub>3</sub> OH 10/0.5) 506	515
121-126	141-143	233-234	199-202	122-126		131-133
T-0 T-0	99	39	9	CH <sub>2</sub>	z	HOP-
2	Z	æ	æ	3	2	9
PO-N N-OHO	F N N-OH,	N-CH <sub>2</sub>	N	CH <sub>3</sub> -O	CH <sub>3</sub>	QH NH
138	139	140	141	142	143	144

	260	485	447	0.50 (toluene/EtOH 9/1) 477	454	408
	114-115	180-182	129-133		145-146	152-153
	3	22	F. O. F.	7	O, CH <sub>3</sub>	CH <sub>2</sub>
	<b>5</b>	7	ע			7
	0H2-0	OH2 N	2	P. H.	CH <sub>2</sub>	н
145		146	147	148	149	061

	<del></del>	
499	506	417
210-211	148-149	236-237
#-0 #-0	F. C.	3
9	=	*
OH <sub>3</sub>	OHO N-OHO	
151	152	153

Compounds of Examples 1 to 153 are typically selective inhibitors of cathepsin K and generally have IC<sub>50</sub>s for inhibition of human cathepsin K of from about 100 to about 1 nM or less, e.g. about 0.5nM.

Representative compounds e.g. as described in the the above Examples typically have  $IC_{50}s$  for inhibition of Cathepsin K in the range from less than 1 up to about 100 nm, and  $IC_{50}s$  for inhibition of Cathepsin K which are at least 10 to about 1000 times less than their  $IC_{50}s$  for inhibition of Cathepsin L and Cathepsin S, e.g. when tested in the assays described above.

The cathepsin K selective compounds of the invention are particularly indicated for preventing or treating osteoporosis of various genesis (e.g. juvenile, menopausal, post-menopausal, post-traumatic, caused by old age or by cortico-steroid therapy or inactivity).

By repeating the procedures described in the above Examples using appropriate starting materials and reaction conditions the following compounds of formula XVII are obtained as identified below in Tables 8, 9 and 10

Table 8

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1) Rf (solvent)
154	(I)	CH <sub>2</sub>	Н	169-170	574 (M-1)
155	CH CH	CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	H		0.80(n- hexane/Et OAC=1/1)

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1) Rf (solvent)
156	0 Z /	E CH <sub>2</sub> CH <sub>3</sub> CH CH <sub>3</sub>	Н		0.63(n- hexane/Et OAC=1/2)
157	CH <sub>2</sub> CH	E CH <sub>2</sub> CH <sub>3</sub> CH 1 CH <sub>3</sub>	Н		0.53(n- hexane/Et OAC=1/1)
158		E CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub>	Н		0.38(n- hexane/Et OAC=1/1)
159	CH <sub>2</sub> CH	CH <sub>2</sub>	Н		422.2
160	F	CH <sub>2</sub>	Н		365.1
161	s c	E CH <sub>2</sub> NH	Н		353
162	Z=Z	CH <sub>2</sub>	Н		315.1
163	N	GH <sub>2</sub>	H		314.9
164		E CH <sub>2</sub>	Н		304.1
165	(\$)	CH <sub>3</sub> CH <sub>3</sub>	Н		259.1

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1) Rf (solvent)
166	<u> </u>	CH3 CH3	Н		288.1
167	C-(-)	CH <sub>3</sub> CH <sub>3</sub>	Н		322
168		CH <sub>3</sub> CH <sub>3</sub>	Н		318.1
169	CH	CH <sub>3</sub>	Н		378.5
170		S— CH <sub>2</sub>	Н		313.9
171	CH <sub>3</sub>	S—S—S—CH <sub>2</sub>	H		327.9
172	cı C	S—S CH <sub>2</sub>	<b>H</b>		349.9
173.	CI CI	S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—	H		383.7
174	CI	S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—S—	. Н		349.8
175	O-CH <sub>3</sub>	S	Н		343.9

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Example	R <sub>x</sub>	R <sub>y</sub>	R <sub>z</sub>	mp.(°C)	MS (M+1)
		1			Rf (solvent)
176	CH <sub>2</sub>	S CH <sub>2</sub>	H		327.9
177	CH <sub>2</sub> CH <sub>2</sub>	S CH <sub>2</sub>	Н		341.9
178	N N	N	Н		315.2
179	\s\	S— CH <sub>2</sub>	H		319.9
180	F	S CH <sub>2</sub>	Н		332
181	) = \( \)	CH <sub>2</sub>	Н		348.1
182	CI	CH <sub>2</sub>	Н		381.3
183	CH <sub>3</sub> O	CH <sub>2</sub>	Н		344.0
184	CI	CH2	Н		347.9
185	CH <sub>3</sub>	CH <sub>2</sub>	Н		344.0

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Example	R <sub>x</sub>	Ry	Rz	mp.(°C)	MS (M+1) Rf (solvent)
186		CH <sub>2</sub>	Н		320
187		CH <sub>2</sub>	H		370
188	CH <sub>3</sub>	CH <sub>2</sub>	H		328
189		CH <sub>2</sub>	H		313.8
190	CH <sub>3</sub>	CH <sub>2</sub>	H		332
191	○ N /	Ē CH₂	Н		322.9
192	CH3	CH <sub>2</sub>	H		381.8
193	F	CH <sup>2</sup>	Н		332
194	NO <sub>2</sub>	CH <sub>2</sub>	Н		358.8

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Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1) Rf (solvent)
195	H <sub>2</sub> C.O	CH <sub>2</sub>	Н		357.9
196	_}_ο=ς	CH <sub>2</sub>	Н		338.8
197	CH <sub>3</sub>	CH2	Н		275.9
198	STN N	CH <sub>2</sub>	Н		397.9
199	NH NH	CH <sub>2</sub>	Н		352.9
200	CH3	CH <sub>2</sub>	Н		316.9
201	CH <sub>3</sub>	CH <sub>2</sub>	Н		392
202	CH <sub>3</sub>	CH <sub>2</sub>	H		360.8
203		CH <sub>2</sub>	*		330

Example	R <sub>x</sub>	R <sub>y</sub>	R <sub>z</sub>	mp.(°C)	MS (M+1) Rf (solvent)
204	ZEO-(=)	CH <sub>2</sub>			365
205	F-(-)	CH <sub>2</sub>			358
206		Ē CH <sub>2</sub>			396
207	CH <sub>3</sub>	E CH₂			370
208	G	CH <sub>2</sub>	$\triangle$		374
209	CH <sub>3</sub>	CH <sub>2</sub>			370
210	CH <sub>3</sub>	CH <sub>2</sub>			354
211	O N	CH <sub>2</sub>			345.1
212	zec-(-)	E CH <sub>2</sub> CH <sub>3</sub> CH CH <sub>3</sub>			325

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1) Rf (solvent)
213	F	E CH <sub>₹</sub> CH <sub>3</sub> CH <sub>3</sub>			318
214	a C	CH <sub>2</sub> CH <sub>3</sub> CH CH <sub>3</sub>			368
215	CI	CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub>			307.9

<sup>\*</sup>  $\triangle$  is cyclopropyl, i.e. Rz is ethylene and makes a cyclopropyl ring with the carbon atom to which it is attached.

The compounds of Table 8 are typically selective inhibitors for cathepsin S, and normally have IC<sub>50</sub>s for cathepsin S inhibition in the range from abot 100 to about 10 nM.

Table 9

Example	R <sub>x</sub>	R <sub>y</sub>	R <sub>z</sub>	mp.(°C)	MS (M+1)
216	Ç, ÇH	CH <sub>2</sub>	H	184-185	432
217	○ CH	CH <sub>2</sub>	: <b>H</b>	181-182	412
218	CH CH	CH <sub>2</sub>	' <b>H</b>	188-189	448
219	CH <sub>2</sub> CH <sub>3</sub>	CH <sub>3</sub>	H	168-169	` 364
220	○ cH	CH <sub>2</sub>	Δ	208-209	438
221	Z = CH	CH <sub>3</sub>	Н	146-148	413
222	○ ot O	CH <sub>2</sub>	Н	194-195	483
223	S CH	CH <sub>2</sub>	Н	186-187	418

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1)
224	S <sub>CH</sub>	CH <sub>3</sub>	Н	176-177	418
225	CI	CH <sub>2</sub>	Н	174-175	391
226	F C F	CH <sub>2</sub>	Н		390
227	F C F	CH <sub>2</sub>	Н	180-181	440
228	CH <sub>3</sub>	CH <sub>3</sub>	Н		352
229	O J.	CH <sub>3</sub>	Н	139-140	562
230	○ CH	CH <sub>3</sub>	CH <sub>3</sub>	180-181	440
231		CH <sub>3</sub>	, c , - c ,	151-153	485

Example	R <sub>x</sub>	R <sub>y</sub>	R <sub>z</sub>	mp.(°C)	MS (M+1)
232	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	NH CH <sub>2</sub>	<b>H</b>	112-114	407
233	CH <sub>3</sub> CC CH <sub>3</sub> CH <sub>3</sub>	S CH <sub>2</sub>	<b>H</b>		424.3
234			H		399.4
235	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>3</sub> CH <sub>2</sub>	<b>H</b>		382
236	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	S CH <sub>2</sub>	- <b>H</b>		468.0
237	CH <sub>3</sub> N CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>		<b>H</b>		394.2

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1)
238	CH <sub>3</sub> N CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub>	Н		444.3
239	CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub>	Н		444.2
240	a	CH <sub>2</sub> CI	Н		411.9
241	CH <sub>3</sub>	CH <sub>2</sub> CI	Н		390.1
242	CI	CH <sub>2</sub> CI	Н		445.9
243	CH <sub>3</sub> -O	CH <sub>2</sub> CI	Н		406.0
244	F C F F	CH <sub>2</sub> CI	Н		461.9
245	F C F F	CH <sub>2</sub> CI	Н		443.7
246	F	CH <sub>2</sub> CI	Н		411.7

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1)
247	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> CI	H		435.8
248	CH <sub>2</sub> N CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	EH <sub>2</sub> CI	Н		511.9
249	a	CH <sub>2</sub> CI	H		445.5
250	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	S CH <sub>2</sub>	Н		429.4
251	CI	CH <sub>2</sub> CI	Н		376
252	<del></del>	CI CI	Н		356
253	` <u></u>	CH <sub>2</sub> CI	Н		372

Example	R <sub>x</sub>	R <sub>y</sub>	R <sub>z</sub>	mp.(°C)	MS (M+1)
254	F C F	E CH <sub>2</sub> CI	Н		427.9
255	F F	CH <sub>2</sub> CI	Н		410
256	# # # # # # # # # # # # # # # # # # #	CH <sub>2</sub> CI	Н		477.9
257	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> CI	Н		402
258	CH <sub>2</sub> N CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> CI	Н		478
259	CI C	CH <sub>2</sub> CI	Н		409.9
260	CH <sub>3</sub> O	CH <sub>2</sub>	Н	134-135	350 (M-1)

Example	R <sub>x</sub>	R <sub>y</sub>	R <sub>z</sub>	mp.(°C)	MS (M+1)
261	F F	CH <sub>3</sub>	H	122-124	388 (M-1)
262	CI	CH <sub>2</sub> F	- -   		360.0
263	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> F	H		385.9
264	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> F	H		461.9
265	a	CH <sub>2</sub> F	<b>H</b>		393.8
266	CI CI	CH <sub>2</sub>	' <b>H</b>		411.7

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1)
267	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> F	Н		408.0
268	CH <sub>2</sub> N CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> F	Н		480.0
269	0	CH <sub>2</sub> F	Н		411.8
270	CH2-0	CH <sub>2</sub> Ci	Н		385.9
271	CH <sub>3</sub>	E CH <sub>2</sub> Ci	Н		369.9
272	CH <sub>3</sub> -C CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> CI	Н		402
273	CH <sub>3</sub> N CH <sub>3</sub> CC CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub>	^		408

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1)
274	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>		Н		394
275	CH <sub>2</sub> -O	CH <sub>2</sub> CI	Н		421
276	CH3 CH3	CH <sub>2</sub> CI	H		409
277	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> CI	Н		437
278	CI	ECH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	Н		307.9
279	CI CI	CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub>	Н		341.7
280	CH <sub>3</sub> C N CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	E CH <sub>2</sub> CC <sup>CH<sub>3</sub></sup> CH <sub>3</sub>	Н		333.9
281	CH <sub>3</sub>	ECH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	Н		302.1

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Example	R <sub>x</sub>	R <sub>y</sub>	R <sub>z</sub>	mp.(°C)	MS (M+1)
282	CH <sub>3</sub> -C CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub>	Н	150-151	382
283	CH <sub>3</sub> N H CH <sub>3</sub> /C	CH <sub>2</sub> NH	Н		393
284	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	NH			433
285	CH <sub>3</sub> CH <sub>2</sub> CH <sub>3</sub> N-N CH <sub>2</sub>	CH <sub>2</sub>	Н		458.3
286	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	EH <sub>2</sub>	Н		450.2
287	C	CH <sub>2</sub> CI	-CH₃		424.1
288	a—Ç—	CH <sub>2</sub> CI	-CH₃		457.3
289	CH3 CH3	CH <sub>2</sub> CI	-CH₃		417.9

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1)
290	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> CI	-CH <sub>3</sub>		449.8
291	F F F	CH <sub>2</sub> CI	-CH₃		457.8
292	CH <sub>3</sub> C N CH <sub>3</sub> C CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> CI	-CH₃		449.9
293	CH <sub>3</sub> CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub>	CH <sub>2</sub> CI	-CH₃		525.9
294	a	CH <sub>2</sub> CI	-CH <sub>3</sub>		457.7
295	CH <sub>3</sub> CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub>		-CH₃		452.1

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1)
296	CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	CH <sub>2</sub> CI	Δ.		428.2

The compounds of Table 9 are typically selective inhibitors for cathepsin L, having IC<sub>50</sub>S for cathepsin S inhibition which are preferably in the range from about 100 to about 1 nM.

Table 10

Example	R <sub>x</sub>	R <sub>y</sub>	R <sub>z</sub>	mp.(°C)	MS (M+1)
297	C)-CH	CH <sub>2</sub>	Н	181-183	398
298	O-cH	CH <sub>3</sub>	H	169-170	912
299	<u>-</u>	CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub>	$\triangle$		333.9
300	CH <sub>3</sub> CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub>	CH <sub>2</sub> CH <sub>3</sub>	Н		410.1

Example	R <sub>x</sub>	R <sub>y</sub>	Rz	mp.(°C)	MS (M+1)
301	CI	CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> CH <sub>3</sub>	Н		434.7

The compounds of Table 10 are inhibitors of cathepsin L and cathepsin S, having IC<sub>50</sub>s for inhibition of cathepsin L in the range from about 100 to about 50 nM and IC<sub>50</sub>s for inhibition of cathepsin S in the range from about 50 to about 10 nM.

# Example 302 Synthesis of N-[2-[(3-(methoxy-carbonyl)-phenyl)-methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenyl-alaninamide

### A. O-[[3-(methoxycarbonyl)-phenyl]methyl]-N-(t-butoxycarbonyl)-L-serine

To a solution of N-(t-butoxycarbonyl)-L-serine (16.1 g, 78.46 mmol) in DMF (90 mL) at -15°C is added sodium hydride (6.9 g, 60% in mineral oil, 172.6 mmol) portionwise with vigorous stirring, over 0.5 hour. After all sodium hydride is added, the mixture is stirred for an additional 10 minutes at 0°C, and then at room temperature for 30 minutes. The solution is cooled back to 0°C, and a solution of methyl 3-bromomethylbenzoate (19.77 g, 86.30 mmol) in DMF (90 mL) is added dropwise over 15 minutes. The mixture is then warmed to room temperature for 16 hours. DMF is then evaporated (high vacuum, <40°C), and the residue is diluted with cold water (200 mL) and acidified to pH 4-5 with 1 N HCl. The resulting mixture is extracted with EtOAc (4 x 150 mL). The combined extracts are washed with 0.1 N HCl (2 x 300 mL) and brine (2 x 300 mL), dried over MgSO4, and evaporated to give a yellowish syrup. Chromatography (silica, 5% MeOH/CH<sub>2</sub>Cl<sub>2</sub>) yields O-[[3-(methoxycarbonyl)-phenyl]methyl]-N-(t-butoxycarbonyl)-L-serine as a yellowish oil.

### B. O-[[3-(methoxycarbonyl)phenyl]methyl]-N-(t-butoxycarbonyl)-L-serinamide

A solution of O-[[3-(methoxycarbonyl)phenyl]methyl]-N-(t-butoxycarbonyl)-L-serine (3.0 g, 8.50 mmol) and N-methylmorpholine (2.8 mL, 2.58 g, 25.5 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (50 mL) is cooled to -10°C, and isobutyl chloroformate (1.1 mL, 1.16 g, 8.5 mmol) is added dropwise over 10 minutes.

After stirring for 15 minutes, ammonia gas is bubbled into the solution at a moderately vigorous rate for 15 minutes. The solution is then warmed to room temperature over 30 minutes. CH<sub>2</sub>Cl<sub>2</sub> is evaporated, and the residue is dissolved in EtOAc (50 mL). This solution is then extracted with 1 N HCl (2 x 50 mL), saturated NaHCO<sub>3</sub> (50 mL), water (50 mL) and brine (50 mL), dried over MgSO<sub>4</sub>, and evaporated. Chromatography (silica, 75% EtOAc/hexane) yields O-[[3-(methoxycarbonyl)phenyl]methyl]-N-(t-butoxycarbonyl)-L-serinamide as a thick oil.

#### C. O-[[3-(methoxycarbonyl)phenyl]methyl]-L-serinamide·HCl

To a solution of O-[[3-(methoxycarbonyl)phenyl]methyl]-N-(t-butoxycarbonyl)-L-serinamide (2.4 g, 6.82 mmol) in EtOAc (50 mL) at 0°C is bubbled HCl gas at a moderately vigorous rate for 5 minutes, during which time a lot of white precipitate is observed. The mixture is warmed to room temperature over 30 minutes, after which time EtOAc is removed, yielding O-[[3-(methoxycarbonyl)phenyl]methyl]-L-serinamide-HCl as a white solid.

#### D. 3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanine

To a solution of 3-methyl-L-phenylalanine (1.8 g, 10.06 mmol) and Na<sub>2</sub>CO<sub>3</sub>(3.2 g, 30.18 mmol) in water (150 mL) is added a solution of diphenylacetyl chloride (2.32 g, 10.06 mmol) in THF (150 mL), and the resulting solution is stirred vigorously at room temperature overnight. The THF is then evaporated and the aqueous layer is diluted with 6% aqueous Na<sub>2</sub>CO<sub>3</sub> (100 mL), and washed with Et<sub>2</sub>O (3 x 150 mL). The aqueous layer is then acidified to pH 1 with conc. HCl, and the resulting slurry is extracted with EtOAc (3 x 100 mL). The organic phase is then washed with water (2 x 100 mL) and brine (1 x 100 mL), dried over MgSO<sub>4</sub> and evaporated to yield 3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanine, as a white solid.

## E. N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-O-[[3-(methoxycarbonyl)phenyl] methyl]-L-serinamide

To a solution of 3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanine (1.0 g, 2.68 mmol) and O-[[3-(methoxycarbonyl)phenyl]methyl]-L-serinamide HCl (0.774 g, 2.68 mmol), 1-hydroxybenzotriazole hydrate (0.452 g, 2.95 mmol, and N-methylmorpholine (1.18 mL, 1.085 g, 10.72 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (50 mL) is added 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide HCl (0.771 g, 4.02 mmol) in one portion and the mixture is stirred at room temperature for 16 hours. The solution is then washed with 1 N HCl (100 mL), saturated aqueous NaHCO<sub>3</sub> (1 x 50 mL), water (1 x 50 mL) and brine (1 x 50 mL), dried over MgSO<sub>4</sub>, and evaporated. The residual solid is

triturated with hot methanol to yield N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-O-[[3-(methoxycarbonyl)phenyl]methyl]-L-serinamide as a white solid.

F. N-[2-[(3-(methoxy-carbonyl)-phenyl)-methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenyl-alaninamide

Oxalyl chloride (0.057 mL, 0.084 g, 0.66 mmol) is added dropwise to DMF (10 mL), and the resulting solution is cooled to 0°C. After the solution becomes clear, pyridine (0.11 mL, 0.10 g, 1.31 mmol) is added, followed by N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-O-[[3-(methoxy-carbonyl)-phenyl]methyl]-L-serinamide (0.20 g, 0.329 mmol), in one portion. The yellow reaction solution is stirred at 0°C for 1.5 hours, after which time the it is diluted with EtOAc (50 mL), and washed with saturated NaHCO3 (1 x 50 mL), saturated LiCl (1 x 50 mL), dried over MgSO4, and evaporated. The residue is chromatographed (silica, 80% EtOAc/hexane) to yield N-[2-[(3-(methoxy-carbonyl)-phenyl)-methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenyl-alaninamide as a white solid having the following structure

## Example 303 Synthesis of N-[2-[(3-carboxyphenyl)methoxy]-1(S)-cyanoethyl]-3-methyl- $N\alpha$ - (diphenyacetyl)-L-phenylalaninamide

A solution of N-[2-[(3-(methoxycarbonyl)phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalaninamide (0.34 g, 0.58 mmol) in pinacolone (20 mL) is degassed with bubbling nitrogen for 10 minutes. Lithium iodide (0.78 g, 5.80 mmol) is then added, and the solution is refluxed in the dark for 24 hours, after which time it is cooled to room temperature, diluted with ethyl acetate (50 mL), and washed with 5% aq. sodium thiosulfate (2 x 50 mL), water (1

x 50 mL) and brine (1 x 50 mL). The organic layer is then dried over Mg\$O4, evaporated, and the residue is chromatographed (silica, 3% MeOH/CH2Cl2/ 0.05% acetic acid) to yield a clear glass, which is crystallized with an EtOAc/hexane (1:50) mixture to yield N-[2-[(3 $carboxyphenyl) methoxy]-1(S)-cyanoethyl]-3-methyl-N\alpha-(diphenyacetyl)-1 L-phenylalanina mide \ as \ a$ white solid, m.p. 160-162°C.

### Example 304 N-[2-[(3-(allyloxycarbonyl)-phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(Nmorpholinocarbonyl)-L-phenylalaninamide

#### A. 3-methyl-N-(t-butoxycarbonyl)-L-phenylalanine

To a suspension of 3-methyl-L-phenylalanine (2.7 g, 15 mmol) in 85 mL 10% triehylamine/methanol is added di-t-butyldicarbonate (6.5 g, 30 mmol), and the solution is refluxed for 2.5 hours. After cooling, the methanol and triethylamine are evaporated and the residue is diluted with Et2O (250 mL) and extracted with saturated Na2CO3 (2 x 75 mL). The combined aqueous layers are again washed with Et<sub>2</sub>O (250 mL), and then acidified with conc. HCl to pH = 2-3. The resulting mixture is then extracted with EtOAc (3 x 75 mL) and washed with water and brine, dried over MgSO<sub>4</sub>, and evaporated to yield 3-methyl-N-(t-butoxycarbonyl)-L-phenylalanine as a clear oil.

#### В. allyl 3-(chloromethyl)-benzoate

A solution of 3-(chloromethyl)-benzoic acid (50.0 g, 0.293 mol), potassium carbonate (48.61 g, 0.352 mol) and allyl bromide (50.7 mL, 0.586 mol) in acetone (500 mL) is refluxed for 2 hours, after which time the solution was cooled to room temp. and filtered through celite. The filtrate is evaporated and the residue chromatographed (silica, 5 % EtOAc/hexane) to yield allyl 3-(chloromethyl)-benzoate as a clear oil.

#### C. allyl 3-(iodomethyl)-benzoate

A solution of allyl 3-(chloromethyl)-benzoate (54.5 g, 0.259 mmol) and sodium iodide (46.56 g, 0.311 mol) in acetone (500 mL) is stirred at room temp. for 6.5 hours, after which time the mixture is filtered. The filitrate is evaporated and the residue is dissolved in diethyl ether (500 mL), then washed with water (1 x 200 mL), 5% sodium sulfite solution (1 x 200 mL) and brine (1 x 200 mL), dried over magnesium sulfate, and evaporated to yield allyl 3-(iodomethyl)-benzoate as a white solid, which was is directly.

#### D. O-[[3-(allyloxycarbonyl)-phenyl]methyl]-N-(t-butoxycarbonyl)-L-serine

Sodium hydride (19.4 g, 60% in mineral oil, 484.4 mmol) is washed with dry hexanes (2 x 30 mL) to remove the mineral oil and then suspended in anhydrous DMF (330 mL). To this suspension a solution of N-butoxycarbonyl-L-serine (45.2 g, 220.2 mmol) in DMF (110 mL) at 0°C is added dropwise with vigorous stirring. The mixture is stirred for an additional 5 minutes at 0°C, and then at room temperature for 30 minutes. The solution is cooled back to 0°C, and a solution of allyl 3-iodomethylbenzoate (66.6 g, 220.2 mmol) in DMF (110 mL) is added dropwise over 15 minutes. The mixture is then warmed to room temperature for 30 minutes. The reaction mixture is poured into ice water (2.2 L) and acidified to pH 2 with 1 N HCl (270 mL). The mixture is extracted with ether (1 x 600 mL, then 3 x 300 mL) and the combined ether extracts are then washed with water (5 x 200 ml) and then dried (MgSO<sub>4</sub>) and evaporated in vacuo to yield O-[[3-(allyloxycarbonyl)-phenyl]methyl]-N-(t-butoxycarbonyl)-L-serine as a yellowish oil, which is used as is in the subsequent step.

### E. O-[[3-(allyloxycarbonyl)phenyl]methyl]-N-(t-butoxycarbonyl)-L-serinamide

A solution of O-[[3-(allyloxycarbonyl)phenyl]methyl]-N-(t-butoxycarbonyl)-L-serine (79.2 g, 209 mmol) and N-methylmorpholine (68.9 mL, 63.4 g, 627 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (800 mL) is cooled to -10°C, and isobutyl chloroformate (32.5 mL, 34.2 g, 251 mmol) is added dropwise over 10 minutes. After stirring for 15 minutes, ammonia gas is bubbled into the solution at a moderately vigorous rate for 15 minutes, at -10°C. The solution is then warmed to room temperature and stirred for 30 minutes. The reaction mixure is cooled to 0°C and 1 N HCl (800 mL) is added. The organic phase is washed with 1 N HCl (2 x 700 mL), then washed with saturated NaHCO<sub>3</sub> (700 mL), then dried (MgSO<sub>4</sub>) and evaporated in vacuo to yield O-[[3-(allyloxycarbonyl)phenyl]methyl]-N-(t-butoxycarbonyl)-L-serinamide as a thick oil, which is used as is in the subsequent step.

### F. O-[[3-(allyloxycarbonyl)phenyl]-methyl]-L-serinamide-HCl

To a solution of O-[[3-(allyloxycarbonyl)phenyl]methyl]-N-(t-butoxycarbonyl)-L-serinamide (69 g, 182.5 mmol) in EtOAc (1000 mL) at 0°C is slowly bubbled HCl gas for 1 hour, during which time a white precipitate is observed. The mixture is warmed to room temperature over 30 minutes, after which time EtOAc is removed by evaporation. The resulting residue is triturated with ether (500 mL) with vigorous stirring for 30 minutes. The precipitate is collected by vacuum filtration, washed with ether (2 x 100 mL) and then air dried to yield O-[[3-(allyloxycarbonyl)phenyl]-methyl]-L-serinamide-HCl as a free-flowing white solid.

## G. N-[3-methyl-N-(t-butoxycarbonyl)-L-phenylalanyl]-O-[[3-(allyloxycarbonyl)-phenyl]methyl]-L-serinamide

To a solution of O-[[3-(allyloxycarbonyl)phenyl]methyl]-L-serinamide•HCl (2.92 g, 10.46 mmol), 3-methyl-N-(t-butoxycarbonyl)-L-phenylalanine (3.29 g, 10.46 mmol), 1-hydroxybenzotriazole (1.92 g, 12.55 mmol), and N-methylmorpholine (4.6 mL, 4.23 g, 41.84 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (120 mL) is added 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide·HCl (3.01 g, 15.69 mmol) in one portion. The solution is stirred for 16 hours, then washed with 1 N HCl (100 mL), saturated aqueous NaHCO<sub>3</sub> (1 x 50 mL), water (1 x 50 mL) and brine (1 x 50 mL), dried over MgSO<sub>4</sub>, and evaporated. The residual solid is triturated with hot methanol to yield N-[3-methyl-N-(t-butoxycarbonyl)-L-phenylalanyl]-O-[[3-(allyloxycarbonyl)-phenyl]methyl]-L-serinamide as a white solid.

## H. N-[2-[(3-(allyloxycarbonyl)-phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(t-butoxycarbonyl)-L-phenylalaninamide

Oxalyl chloride (1.79 mL, 2.6 g, 20.48 mmol) is added dropwise to DMF (30 mL), and the resulting solution is cooled to 0°C. After the solution becomes clear, pyridine (3.31 mL, 3.24 g, 40.96 mmol) is added, followed by N-[3-methyl-N-(t-butoxycarbonyl)-L-phenylalanyl]-O-[[3-(allyloxy-carbonyl)phenyl]methyl]-L-serinamide (5.52 g, 10.24 mmol), in one portion. The yellow reaction solution is stirred at 0°C for 1.5 hours, after which time it is diluted with EtOAc (50 mL), and washed with saturated NaHCO3 (1 x 50 mL), saturated LiCl (1 x 50 mL), dried over MgSO4, and evaporated. The residue is chromatographed (silica, 40% EtOAc/hexane) to yield N-[2-[(3-(allyloxycarbonyl)-phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(t-butoxycarbonyl)-L-phenylalaninamide as a white solid.

## I. N-[2-[(3-(allyloxycarbonyl)-phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-L-phenylalaninamide

A solution of N-[2-[(3-(allyloxycarbonyl)-phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-N $\alpha$ -(t-butoxycarbonyl)-L-phenylalaninamide (3.18 g, 6.10 mmol) in 96% formic acid (40 mL) is stirred at room temperature for 5.5 hours. Formic acid is evaporated (high vacuum, 25°C), and the residue is taken up in water (50 mL) and basified with saturated NaHCO3 (100 mL). The resulting mixture is extracted with EtOAc (3 x 50 mL), and then washed with water (2 x 100 mL) and brine (1 x 100 mL).

mL), dried over MgSO<sub>4</sub>, and evaporated to yield N-[2-[(3-(allyloxycarbonyl)-phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-L-phenylalaninamide as a clear thick oil.

J. N-[2-[(3-(allyloxycarbonyl)-phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-N $\alpha$ -(N-morpholinocarbonyl)-L-phenylalaninamide

To a solution of N-[2-[(3-(allyloxycarbonyl)phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-L-phenylalaninamide•HCl (0.29 g, 0.69 mmol) and N-methylmorpholine (0.23 mL, 0.21 g, 2.07 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (10 mL) is added mopholinecarbonyl chloride (0.21 g, 0.23 mL, 2.065 mmol) in one portion, and the solution is stirred at room temperature for 16 hours. The solution is then diluted with additional CH<sub>2</sub>Cl<sub>2</sub> (40 mL), and washed with 1 N HCl (50 mL), saturated aqueous NaHCO<sub>3</sub> (1 x 50 mL), water (1 x 50 mL) and brine (1 x 50 mL), dried over MgSO<sub>4</sub>, and evaporated. The residue is chromatographed (silica, 80% EtOAc/hexane) to yield N-[2-[(3-(allyloxycarbonyl)-phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(N-morpholinocarbonyl)-L-phenylalaninamide as a clear oil.

The corresponding 3-carboxyphenylmethoxy compound is prepared as follows:

To a solution of N-[2-[(3-(allyloxycarbonyl)-phenyl)methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(N-morpholinocarbonyl)-L-phenylalaninamide (see example 3, 0.2 g, 0.375 mmol) in anhydrous THF (20 mL) is added morpholine (0.327 mL, 0.326 g, 3.75 mmol), followed by Pd(PPh<sub>3</sub>)<sub>4</sub> (0.043 g, 0.0375 mmol). The solution is stirred at room temperature for 3 hours, after which time the THF is evaporated. The residue is taken up in EtOAc (100 mL) and washed with 1 N HCl (100 mL), saturated aqueous NaHCO<sub>3</sub> (1 x 50 mL), water (1 x 50 mL) and brine (1 x 50 mL), dried over MgSO<sub>4</sub>, and evaporated. The residue is chromatographed (silica, 3% MeOH/CH<sub>2</sub>Cl<sub>2</sub>/ 0.05% acetic acid) to yield a clear glass, which is crystallized with an EtOAc/hexane (1:50) mixture to yield N-[2-[(3-carboxyphenyl)-methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(N-morpholinocarbonyl)-L-phenylalaninamide as a white solid, m.p. 100 °C (dec.).

Example 305 Synthesis of N-[3-(3-(methoxycarbonyl)-phenoxy)-1-cyanopropyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalaninamide

A. <u>methyl 3-(2-bromoethoxy)-benzoate</u>

VEDOCID: JMO

A solution of methyl 3-hydroxybenzoate (5.0g, 32.86 mmol), 1,2-dibromoethane (11.3 mL,

131.44 mmol), and potassium carbonate (5.45 g, 39.43 mmol) in DMF (100 mL) is refluxed 16 hours, after which time the solution is cooled, concentrated *in vacuo*, and chromatographed to yield methyl 3-(2-bromoethoxy)-benzoate, as a yellow oil.

#### B. methyl 3-(2-iodoethoxy)-benzoate

A solution of methyl 3-(2-bromoethoxy)-benzoate (2.4 g, 9.26 mmol) and sodium iodide (2.78 g, 18.52 mmol) in acetone (50 mL) is refluxed for 2 hours. The resulting mixture is then filtered and concentrated. The residue is diluted with EtOAc (100 mL), washed with 5% Na<sub>2</sub>SO<sub>3</sub>(50 mL), water (2 x 50 mL) and brine (50 mL), dried over MgSO<sub>4</sub> and evaporated to yield methyl 3-(2-iodoethoxy)-benzoate, as a yellow oil, which is used directly.

#### C. 2-(diphenylmethyleneamino)-4-[(3-methoxycarbonyl)-phenoxy]-butyronitrile

To a solution of sodium hexamethyldisilazide (8.82 mL of a 1.0 M solution, 8.82 mmol) in 90 mL THF at -78°C is added a solution of N-(diphenylmethylene)aminoacetonitrile (1.90 g, 8.65 mmol) in THF (30 mL), via syringe. After stirring 30 minutes at -78°C, a solution of methyl 3-(2-iodoethoxy)-benzoate (2.7 g, 8.82 mmol) in THF (20 mL) is added in to the reaction solution via syringe. The solution is then warmed to room temperature, and allowed to stir for 3 hours. The mixture is then quenched with saturated NH4Cl (50 mL), and the aqueous layer is extracted with EtOAc (3 x 50 mL). The combined organic layers are washed with water (1 x 50 mL) and brine (1 x 50 mL), and chromatographed (silica, 12.5% EtOAc/hexane) to yield 2-(diphenylmethyleneamino)-4-[(3-methoxycarbonyl)-phenoxy]-butyronitrile, as a clear oil.

#### D. 2-amino-4-[3-(methoxycarbonyl)-phenoxy]-butyronitrile

2-(Diphenylmethyleneamino)-4-[(3-methoxycarbonyl)-phenoxy]-butyronitrile (3.7 g, 6.78 mmol) is stirred vigorously for 16 hours in a biphasic mixture of 1 N HCl (7.5 mL) and Et<sub>2</sub>O (90 mL). The ether layer is removed, and the aqueous layer is washed with Et<sub>2</sub>O (3 x 50 mL), basified to pH 8 with 1 N NaOH, and extracted with EtOAc (3 x 50 mL). The combined organic layers are then washed with brine (1 x 50 mL), dried over MgSO<sub>4</sub> and evaporated to yield 2-amino-4-[3-(methoxycarbonyl)-phenoxy]-butyronitrile, as a clear oil.

## E. N-[3-(3-(methoxycarbonyl)-phenoxy)-1-cyanopropyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalaninamide

To a solution of 2-amino-4-[3-(methoxycarbonyl)-phenoxy]-butyronitrile (0.5 g, 2.13 mmol), 3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanine (see example 1, 0.80 g, 2.13 mmol) and

diisopropylethylamine (1.1 mL, 6.39 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (15 mL) is added benzotriazol-1-yloxy-tris-(pyrrolidino)-phosphonium hexafluorophosphate (PyBop, 1.22 g, 2.34 mmol) in one portion. After stirring 1.5 hour, an additional portion of PyBop (0.61 g, 1.2 mmol) is added, and the solution is stirred overnight. The reaction mixture is washed with 1 N HCl (50 mL), saturated aqueous NaHCO<sub>3</sub> (1 x 50 mL), water (1 x 50 mL) and brine (1 x 50 mL), dried over MgSO<sub>4</sub>, and evaporated. The residue is chromatographed (silica, 50% EtOAc/hexane) to yield N-[3-(3-(methoxycarbonyl)-phenoxy)-1-cyanopropyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide as a white solid, m.p. 152-153°C.

The corresponding carboxyphenoxy compound is prepared as follows:

To a solution of N-[3-(3-(methoxycarbonyl)-phenoxy)-1-cyanopropyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide (0.16 g, 0.272 mmol) in THF (3 mL) is added a solution of LiOH·H<sub>2</sub>O (22 mg, 0.544 mmol) in water (1.5 mL). The reaction is stirred for 1 hour, after which time the THF is evaporated. The residue is acidified with 1 N HCl and extracted with EtOAc (3 x 30 mL). The aqueous layer is washed with brine (30 mL), dried over MgSO<sub>4</sub>, evaporated and chromatographed (5% MeOH, 0.05% AcOH, CH<sub>2</sub>Cl<sub>2</sub>) to yield N-[3-(3-carboxyphenoxy)-1-cyanopropyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide, as a white solid, m.p. 169-170°C.

Example 306 Synthesis of N-[2-[(5-(methoxycarbonyl)-fur-2-yl)-methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalaninamide

#### A. 5-(bromomethyl)-2-furoate

To a solution of 5-methylfurfural (5.0 g, 45.5 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) is added pulverized N-bromosuccinimide (17.8 g, 100 mmol), and the solution is subjected to sun lamp irradiation. After 15 minutes, the solution begins to reflux vigorously, and then settles down after another 2-3 minutes. After an additional 10 minutes, the dark mixture is cooled to room temperature, and MeOH (30 mL) is added. After 10 minutes, the solution is evaporated, and the residue is diluted with Et<sub>2</sub>O, and washed with saturated NaHCO<sub>3</sub> (50 mL), water (50 mL) and brine (50 mL), dried over MgSO<sub>4</sub> and evaporated. The residue is chromatographed (silica, 15% EtOAc/hexane) to yield methyl 5-(bromomethyl)-2-furoate, as a yellowish oil.

#### B. O-[[(5-methoxycarbonyl)-fur-2-yl]-methyl]-N-(t-butoxycarbonyl)-L-serine

To a solution of N-(t-butoxycarbonyl)-L-serine (2.5 g, 12.3 mmol) in DMF (50 mL) at - 15°C is added sodium hydride (1.22 g, 60% in mineral oil, 30.7 mmol) portionwise with vigorous stirring, over 0.5 hours. After all sodium hydride is added, the mixture is stirred for an additional 10 minutes at 0°C, and then at room temperature for 30 minutes. The solution is cooled back to 0°C, and a solution of methyl 5-(bromomethyl)-2-furoate (2.5 g, 12.3 mmol) in DMF (10 mL) is added dropwise over 2 minutes. The mixture is then warmed to room temperature for 16 hours, and the residue is quenched with 10% NaH2PO4 (100 mL) and acidified to pH 3 with 1 N HCl. 10% LiCl (30 mL) is added to the solution, and the resulting mixture is extracted with EtOAc (3 x 50 mL). The combined extracts are washed with brine (50 mL), dried over MgSO4, and evaporated to give a yellowish syrup. This residue is taken up in Et2O (50 mL), and extracted with Et2O (2 x 50 mL), dried (MgSO4), and evaporated. Chromatography (silica, 5% MeOH/CH2Cl2) yields O-[[(5-methoxycarbonyl)-fur-2-yl]-methyl]-N-(t-butoxycarbonyl)-L-serine as a yellowish oil.

### C. $O-[[(5-methoxycarbonyl)-fur-2-yl]-methyl]-N\alpha-(t-butoxycarbonyl)-L-serinamide$

A solution of O-[[(5-methoxycarbonyl)-fur-2-yl]-methyl]-N-(t-butoxycarbonyl)-L-serine (0.70 g, 2.1 mmol) and N-methylmorpholine (0.46 mL, 4.2 mmol)) in CH<sub>2</sub>Cl<sub>2</sub> (50 mL) is cooled to -10°C, and isobutyl chloroformate (0.27 mL, 2.1 mmol)) is added dropwise over 10 minutes. After stirring for 15 minutes, ammonia gas is bubbled into the solution at a moderately vigorous rate for 15 minutes. The solution is then warmed to room temp. over 30 minutes. CH<sub>2</sub>Cl<sub>2</sub> is evaporated, and the residue is dissolved in EtOAc (50 mL). This solution is then extracted with 1 N HCl (2 x 50 mL), saturated NaHCO<sub>3</sub> (50 mL), water (50 mL) and brine (50 mL), dried over MgSO<sub>4</sub>, and evaporated to yield O-[[(5-methoxycarbonyl)-fur-2-yl]-methyl]-Nα-(t-butoxycarbonyl)-L-serinamide as a brownish solid.

#### D. O-[[(5-methoxycarbonyl)-fur-2-yl]-methyl]- L-serinamide·HCl

To a solution of O-[[(5-methoxycarbonyl)-fur-2-yl]-methyl]-Nα-(t-butoxycarbonyl)-L-serinamide (0.52 g, 1.58 mmol)) in EtOAc (50 mL) at 0°C is bubbled HCl gas at a moderately vigorous rate for 1 minute, during which time a lot of white precipitate is observed. The mixture is stirred at 0°C for 10 minutes, after which time ethyl acetate is removed, yielding O-[[(5-methoxycarbonyl)-fur-2-yl]-methyl]- L-serinamide·HCl as a yellowish solid.

# E. N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-O-[[5-(methoxycarbonyl)-fur-2-yl]-methyl]-L-serinamide

To a solution of 3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalanine (0.40 g, 1.5 mmol), O-[[(5-methoxycarbonyl)-fur-2-yl]methyl]- L-serinamide·HCl (0.54 g, 1.5 mmol), 1-hydroxybenzo triazole hydrate (0.2 g, 1.5 mmol) and N-methylmorpholine (0.66 mL, 6.0 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (30 mL) is added 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide·HCl (0.43 g, 2.3 mmol) in one portion, and the mixture is stirred at room temp. for 16 hours. The solution is then washed with 1 N HCl (100 mL), saturated aqueous NaHCO3 (1 x 50 mL), water (1 x 50 mL) and brine (1 x 50 mL), dried over MgSO4, and evaporated. The residual solid is triturated from ether to yield N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-O-[[5-(methoxycarbonyl)-fur-2-yl]-methyl]-L-serinamide as a light yellow solid.

## F. N-[2-[(5-(methoxycarbonyl)-fur-2-yl)-methoxy]-1(S)-cyanoethyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide

Oxalyl chloride (0.046 mL, 0.36 mmol) is added dropwise to DMF (5 mL), and the resulting solution is cooled to 0°C. After the solution is clear, pyridine (0.032 mL, 0.40 mmol) is added, followed by N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-O-[[5-(methoxycarbonyl)-fur-2-yl]-methyl]-L-serinamide (0.20g, 0.33 mmol), in one portion. The yellow reaction solution is stirred at 0°C for 1.5 hours, after which time it is diluted with EtOAc (50 mL), and washed with saturated NaHCO3 (1 x 50 mL), saturated LiCl (1 x 50 mL), dried over MgSO4, and evaporated. The residue is chromatographed (silica, 40% EtOAc/hexane) to yield N-[2-[(5-(methoxycarbonyl)-fur-2-yl)-methoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalaninamide as a white solid.

## Example 307 Synthesis of N-[2-[(3-(methoxycarbonyl)phenyl)thiomethoxy]-1(S)-cyanoethyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide

#### A. N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-S-trityl-L-cysteinamide

To a solution of 3-methyl-N-(2,2-diphenylacetyl-L-phenylalanine (see example 302, 1.0 g, 2.68 mmol), 1-hydroxybenzotriazole hydrate (0.41 g, 2.68 mmol) and N-methylmorpholine (0.74 mL, 6.69 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (80 mL) is added 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide·HCl (0.77 g, 4.02 mmol) in one portion. After stirring 30 minutes at room temperature, S-trityl-L-cysteinamide (0.97 g, 2.68 mmol) is added to the solution in one portion, and the solution is stirred

for 16 hours. The solution is evaporated, and the residue partitioned between water (80 mL) and ethyl acetate (80 mL). The aqueous layer is washed with EtOAc (2 x 80 mL), and the combined organic layers are then washed with 1 N HCl (100 mL), saturated aqueous NaHCO3 (1 x 50 mL), water (1 x 50 mL) and brine (1 x 50 mL), dried over MgSO4, and evaporated. The residue is triturated with Et<sub>2</sub>O/hexane (1:1) to yield N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-S-trityl-L-cysteinamide as a white solid.

#### B. N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-L-cysteinamide

To a solution of N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-S-trityl-L-cysteinamide (0.68 g, 0.95 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (20 mL) is added triethylsilane (0.30 mL, 1.9 mmol), in one portion, followed by dropwise addition of trifluoroacetic acid (10 mL). The yellow solution is stirred at room temperature for 1 hour, after which time solvent is evaporated, and the residue is suspended in water (30 mL), filtered, and the collected solid is washed with water and ether (100 mL each), and dried *in vacuo*, to yield of N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-L-cysteinamide, as a white solid.

## C. N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-S-[[3-(methoxycarbonyl)phenyl] methyl]-L-cysteinamide

A solution of N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-L-cysteinamide (0.72 g, 1.51 mmol), methyl 3-(bromomethyl)-benzoate (0.35 g, 1.51 mmol), and diisopropylethylamine (0.27 mL, 1.53 mmol) is stirred at room temperature overnight. Solvent is evaporated, and the residue is treated with 1 N HCl (50 mL), and filtered to collect a white solid, which is washed with water and Et<sub>2</sub>O (100 mL each). Drying *in vacuo* yields N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-S-[[3-(methoxycarbonyl)phenyl]methyl]-L-cysteinamide, as a white solid.

## D. N-[2-[(3-(methoxycarbonyl)phenyl)thiomethoxy]-1(S)-cyanoethyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide

Oxalyl chloride (0.29 mL, 2.90 mmol) is added dropwise to DMF (20 mL), and the resulting solution is cooled to 0°C. After the solution becomes clear, pyridine (0.54 mL, 5.8 mmol) is added, followed by N-[3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanyl]-S-[[3-(methoxycarbonyl)-phenyl]-methyl]-L-cysteinamide (0.90 g, 1.51 mmol), in one portion. The yellow reaction solution is stirred at 0°C for 1.5 hours, after which time it is diluted with EtOAc (50 mL), and washed with saturated NaHCO3 (1 x 50 mL), saturated LiCl (1 x 50 mL), dried over MgSO4, and evaporated. The residue

is chromatographed (silica, 33% EtOAc/hexane) to yield N-[2-[(3-(methoxycarbonyl)phenyl)thiomethoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalaninamide as a white solid.

Example 308 N-[2-[(3-carboxyphenyl)methanesulfinyl]-1(S)-cyanoethyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl-L-phenylalaninamide

To a solution of N-[2-[(3-carboxyphenyl)thiomethoxy]-1(S)-cyanoethyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalaninamide (89 mg, 0.15 mmol) in acetone (5 mL) is added a solution of potassium peroxymonosulfate (Oxone®, 0.11 g, 0.18 mmol) in water (5 mL) at 0°C, and the solution is stirred at 0°C for 40 minutes. 5% NaHSO4(10 mL) is added, and the cloudy suspension is filtered. The solid is washed with water (50 mL), dried *in vacuo*, and then recrystalized (CH<sub>2</sub>Cl<sub>2</sub>, Et<sub>2</sub>O) to yield N-[2-[(3-carboxyphenyl)methanesulfinyl]-1(S)-cyanoethyl]-3-methyl-Nα-(2,2-diphenylacetyl-L-phenylalaninamide product, as a white solid, m.p. 170-171°C.

Example 309 N-[4-(3-methoxycarbonyl-1H-pyrazol-1-yl)-1(S)-cyanobutyl]-3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalaninamide

#### A. <u>t-butyl (S)-5-hydroxy-2-(t-butoxycarbonylamino)-pentanoate</u>

To a solution of N-(t-butoxycarbonyl)-L-glutamic acid t-butyl ester (6.0g, 19.78 mmol) and triethylamine (2.83 mL, 20.27 mmol) in THF at -10°C is added ethyl chloroformate (1.94 mL, 20.27 mmol) dropwise, via syringe, and the solution is stirred at -10°C for 30 minutes. The solution is filtered to remove precipitate, and the filtrate is added into a solution of NaBH4 (2.3 g, 60.86 mmol) in THF (40 mL) and water (50 mL). This solution is then stirred for 4 hours, after which time the solution is acidified with 1 N HCl to pH = 5, and THF is evaporated. The aqueous residue is extracted with EtOAc (3 x 200 mL), and the organic layers is then washed with 1 N NaOH (2 x 300 mL), water (300 mL) and brine (300 mL), dried over MgSO4, and evaporated. Chromatography (silica, 20% EtOAc/hexane) yields t-butyl (S)-5-hydroxy-2-(t-butoxycarbonylamino)-pentanoate as a thick oil.

#### B. <u>t-butyl (S)-5-iodo-2-(t-butoxycarbonylamino)-pentanoate</u>

To a solution of t-butyl (S)-5-hydroxy-2-(t-butoxycarbonylamino)-pentanoate (5.79 g, 20.0 mmol), triphenylphosphine (8.13 g, 31.0 mmol) and imidazole (2.04 g, 30.0 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (200

mL) at room temperature is added iodine (6.35 g, 25.0 mmol), portionwise, over 30 minutes. The mixture is then stirred 16 hours at room temperature. Methanol (20 mL) is added to the solution, which is then stirred an additional 1 hour. Solvent is evaporated, and the residue is purified by chromatography (silica, 33% EtOAc/hexane) to yield t-butyl (S)-5-iodo-2-(t-butoxycarbonylamino)-pentanoate as a clear oil.

### C. 3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalanine N-hydroxysuccinimide ester

A solution of 3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanine (see example 1, 10.93 g, 2.5 mmol) in dioxane (50 mL) at 0°C is added N-hydroxysuccinimide (0.29 g, 2.5 mmol) in one portion, followed by a solution of DCC (0.52 g, 2.5 mmol) in dioxane (10 mL), which is added dropwise over 10 minutes. The cloudy mixture is warmed to room temperature overnight, after which time it is cooled back to 0°C, and filtered. The filtrate is evaporated to yield 3-methyl-Nα-(2,2-diphenylacetyl)-L-phenylalanine N-hydroxysuccinimide ester as a white solid.

### D. <u>t-butyl (S)-5-(3-methoxycarbonyl-1H-pyrazol-1-yl)-2-(t-butoxycarbonylamino)-pentanoate</u>

To a solution of methyl 1H-pyrazole 3-carboxylate (Synth. Comm., 25, 1995, 761) (0.98 g, 7.74 mmol) in DMF (20 mL) at 0°C is added NaH (60% suspension, 0.31 g, 7.74 mmol) portionwise, over 10 minutes. After stirring an additional 10 minutes, a solution of t-butyl (S)-5-iodo-2-(t-butoxy-carbonylamino)-pentanoate (2.78 g, 9.29 mmol) in DMF (20 mL) is added over 2 minutes, and the solution is warmed to room temperature over 16 hours. The solvent is evaporated (high-vac), the residue is treated with water (50 mL) and the aqueous layer is extracted with EtOAc (3 x 80 mL). The combined organic layers are washed with water (2 x 200 mL) and brine (100 mL), dried over MgSO4, and evaporated. Chromatography (silica, 25% EtOAc/hexane) yields the two regioisomeric products in a ~2:1 ratio. The minor product, which is determined to be the desired product, t-butyl (S)-5-(3-methoxycarbonyl-1H-pyrazol-1-yl)-2-(t-butoxycarbonylamino)-pentanoate, is isolated as a thick, clear oil.

### E. (S)-5-(-3-methoxycarbonyl-1H-pyrazol-1-yl)-2-aminopentanoic acid·HCl

To a solution of t-butyl (S)-5-(-3-methoxycarbonyl-1H-pyrazol-1-yl)-2-(t-butoxycarbonylamino)-pentanoate(0.84 g, 0.21 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (20 mL) at 0°C is bubbled HCl gas for 30 minutes. Afterward, the solution is warmed to room temperature over 30 minutes. Evaporation of solvent yields (S)-5-(-3-methoxycarbonyl-1H-pyrazol-1-yl)-2-aminopentanoic acid·HCl as a gray-white solid.

# F. N-[4-(3-methoxycarbonyl-1H-pyrazol-1-yl)-1(S)-carboxybutyl]-3-methyl-Na-(2,2-diphenylacetyl)-L-phenylalaninamide

To a solution of (S)-5-(-3-methoxycarbonyl-1H-pyrazol-1-yl)-2-aminopentanoic acid·HCl (0.67 g, 2.13 mmol) in 10 mL water is added a solution of NaHCO<sub>3</sub>(0.72 g, 8.53 mmol) in water (10 mL). After bubbling subsides, a solution of 3-methyl-Na-(2,2-diphenylacetyl)-L-phenylalanine N-hydroxysuccinimide ester (0.67 g, 2.13 mmol) in 20 mL dioxane is added dropwise over 10 minutes, and the solution is stirred at room temperature for 16 hours. Solvent is then evaporated, and the residue is diluted with water (50 mL) and adjusted to pH = 4 with 1 N HCl. The aqueous layer is extracted with EtOAc (3 x 80 mL), and the combined extracts are washed with brine (2 x 100 mL), dried over MgSO<sub>4</sub>, evaporated, and triturated from Et<sub>2</sub>O to yield N-[4-(3-methoxycarbonyl-1H-pyrazol-1-yl)-1(S)-carboxybutyl]-3-methyl-Na-(2,2-diphenylacetyl)-L-phenylalaninamide, which is carried on directly.

## G. N-[4-(3-methoxycarbonyl-1H-pyrazol-1-yl)-1(S)-(aminocarbonyl)-butyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide

A solution of N-[4-(3-methoxycarbonyl-1H-pyrazol-1-yl)-1(S)-carboxybutyl]-3-methyl-Na-(2,2-diphenylacetyl)-L-phenylalaninamide (0.3 g, 0.5 mmol)) and N-methylmorpholine (0.17 mL, 1.5 mmol) in CH2Cl2 (50 mL) is cooled to -10°C, and isobutyl chloroformate (0.065 mL, 0.5 mmol) is added dropwise over 10 minutes. After stirring for 15 minutes, ammonia gas is bubbled into the solution at a moderately vigorous rate for 15 minutes. The solution is then warmed to room temperature over 30 min. CH2Cl2 is evaporated, the residue is treated with water (30 mL). The suspension is adjusted to pH = 7 with 1 N HCl, and filtered. The solid is washed with water (50 mL) and dried *in vacuo* to yield N-[4-(3-methoxycarbonyl-1H-pyrazol-1-yl)-1(S)-(aminocarbonyl)-butyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide.

# $H. \qquad \underline{\text{N-[4-(3-methoxycarbonyl-1H-pyrazol-1-yl)-1(S)-cyanobutyl]-3-methyl-N}\alpha\text{-(2,2-diphenylacetyl)-L-phenylalaninamide}$

Oxalyl chloride (0.082 mL, 0.94 mmol) is added dropwise to DMF (20 mL), and the resulting solution is cooled to 0°C. After the solution becomes clear, pyridine (0.15 mL, 1.88 mmol) is added, followed by N-[4-(3-methoxycarbonyl-1H-pyrazol-1-yl)-1(S)-(aminocarbonyl)butyl]-3-methyl-N $\alpha$ -(2,2-diphenyl-acetyl)-L-phenylalaninamide(0.28 g, 0.47 mmol), in one portion. The yellow reaction solution is stirred at 0°C for 1.5 hours, after which time it is diluted with EtOAc (50

mL), and washed with saturated NaHCO3 (1 x 50 mL), saturated LiCl (1 x 50 mL), dried over MgSO4, and evaporated. The residue is chromatographed (silica, 66% EtOAc/hexane) to yield N-[4-(3-methoxycarbonyl-1H-pyrazol-1-yl)-1(S)-cyanobutyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide as a white solid.

# Example 310 N-[4-(3-methoxycarbonyl-phenyl)-1(S)-cyanobutyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide

### A. N-(t-butoxycarbonyl)-(S)-propargylglycineamide

To a solution of N-(t-butoxycarbonyl)-(S)-propargylglycine (2.44 g, 11.45 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (50 mL) is added N-methylmorpholine (3.78 mL, 34.4 mmol) in one portion. The solution is then cooled to -10°C, and isobutyl chloroformate is added dropwise over 5 minutes. After stirring for 15 minutes, ammonia gas is bubbled into the reaction mixture at a moderately vigorous rate for 15 minutes. The resulting milky suspension is then warmed to room temperature over 2 hours, and the mixture is washed with 1 N HCl (2 x 25 mL), aqueous NaHCO<sub>3</sub> (25 mL) and brine (25 mL), and then dried over MgSO<sub>4</sub>. Evaporation of solvent, followed by chromatography (silica, 65% EtOAc/hexane) yields N-(t-butoxycarbonyl)-(S)-propargylglycineamide, as a clear oil.

### B. (S)-2-(t-butoxycarbonylamino)-5-(3-carbomethoxyphenyl)-4-pentynoic acid amide

A solution of N-(t-butoxycarbonyl)-(S)-propargylglycineamide (1.15 g, 5.33 mmol), methyl 3-bromobenzoate (1.15 g, 5.33 mmol), and Cu(I)I (0.041 g, 0.214 mmol) in triethylamine (25 mL) is deoxygenated with bubbling N<sub>2</sub> for 2-3 minutes. Bis(triphenylphosphine)palladium dichloride (0.075 g, 0.11 mmol) is then added in one portion, and the mixture is refluxed for 3 hours, after which time solvent is evaporated. The residue is then taken up in EtOAc (10 ml), and then washed with 1 N HCl (40 mL) and brine (30 mL), and then dried over MgSO<sub>4</sub>. The residue is chromatographed (silica, 80% EtOAc/hexane) to yield (S)-2-(t-butoxycarbonylamino)-5-(3-carbomethoxyphenyl)-4-pentynoic acid amide, as a light yellow solid.

### C. (S)-2-butoxycarbonylamino-4-(3-carbomethoxyphenyl)-pentanamide

To a solution of (S)-2-(t-butoxycarbonylamino)-5-(3-carbomethoxyphenyl)-4-pentynoic acid amide (1.11 g, 3.22 mmol) in 1:1 ethanol/THF (50 mL) is added 10% Pd/C (0.5 g), and the mixture is hydrogenated at 1 atm. for 1.5 hours. The mixture is filtered through celite, and evaporated to yield (S)-2-butoxycarbonylamino-4-(3-carbomethoxyphenyl)-pentanamide, as a clear oil.

#### E. (S)-2-amino-4-(3-carbomethoxyphenyl)-pentanamide HCl

To a solution of (S)-2-(t-butoxycarbonylamino)-5-(3-carbomethoxyphenyl)-pentanamide (1.22 g, 3.5 mmol) in EtOAc (75 mmol) at 0°C is bubbled HCl gas at a moderately vigorous rate, for 5 minutes. The solution is then warmed to room temperature for 30 minutes Evaportion of solvent yields (S)-2-amino-4-(3-carbomethoxyphenyl)-pentanamide HCl salt as a light yellow solid.

## F. N-[4-(3-methoxycarbonyl-phenyl)-1(S)-(aminocarbonyl)-butyl]-3-methyl-Na-(2,2-diphenylacetyl)-L-phenylalaninamide

To a solution of (S)-2-amino-5-(3-carbomethoxyphenyl)-pentanamide HCl (0.30 g, 0.80 mmol), of 3-methyl-N-(2,2-diphenylacetyl)-L-phenylalanine (0.23 g, 0.80 mmol), 1-hydroxybenzotriazole hydrate (0.135 g, 0.89 mmol) and N-methylmorpholine (0.35 ml, 3.2 mmol) in CH2Cl2 (25 mL) is added 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide·HCl (0.23 g, 1.2 mmol) in one portion, and the mixture is stirred at room temperature for 16 hours. The solution is then washed with 1 N HCl (100 mL), saturated aqueous NaHCO3 (1 x 50 mL), water (1 x 50 mL) and brine (1 x 50 mL), dried over MgSO4, and evaporated. The residual solid is triturated with ether to yield N-[4-(3-methoxycarbonyl-phenyl)-1(S)-(aminocarbonyl)-butyl]-3-methyl-Na-(2,2-diphenylacetyl)-L-phenylalaninamide as a light yellow solid.

## G. N-[4-(3-methoxycarbonyl-phenyl)-1(S)-cyanobutyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide

Oxalyl chloride (0.12 mL, 1.39 mmol) is added dropwise to DMF (10 mL), and the resulting solution is cooled to 0°C. After the solution is clear, pyridine (0.22 mL, 2.78 mmol) is added, followed by N-[4-(3-methoxycarbonylphenyl)-1(S)-(aminocarbonyl)butyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide (0.42 g, 0.70 mmol), in one portion. The yellow reaction solution is stirred at 0°C for 1.5 hours, after which time it is diluted with EtOAc (50 mL), and washed with saturated aqueous NaHCO<sub>3</sub> solution (1 x 50 mL), saturated aqueous LiCl solution (1 x 50 mL), dried over MgSO<sub>4</sub> and evaporated. The residue is chromatographed to yield N-[4-(3-methoxycarbonyl-phenyl)-1(S)-cyanobutyl]-3-methyl-N $\alpha$ -(2,2-diphenylacetyl)-L-phenylalaninamide, as a yellow solid.

By repeating the procedure described above in Examples 302 to 310, using appropriate starting materials and conditions the following compounds of formula XVIII are obtained as identified below in Table 11.

		MS (M+1)				
		mp.(°C)	100 dec.	142-145	171-172	173-175
		7	НООО	¥	22	ä
Table 11	R <sub>30</sub> NH·C-CONH—C-C≡N i x <sub>2</sub> -Ar—Z	-Ar		3	7	3
	A S S T S S S S S	X <sub>2</sub>	CH2 CH2	ą	13	¥
,		R <sub>32</sub>	£	:	н	¥
		R <sub>30</sub>	0)-c0	Och3 Och3 Och3	CH3CO	O=0
		Example	311	312	313	314

SDOCIDE AND DOSAGOAS I

		·		 	•
MS (M+1)					578
mp.(°C)	120 dec.		90 dec.		
7	2		B		3
-Ar	z z		3		**
××	=		5		*
H 22	D.		ž		а
<b>R</b> 30	0=U T O=Z	Isomer 1	0=v 	 Isomer 2	O=0, T O=z
Example	315	316	)	317	

MS (M+1)					522	536
mp.(°C)	139-141	153-155	129-131	170-172		
2	æ	¥	3	я	IJ	¥
-Ar	В	77	н	я	и	я
X <sub>2</sub>	<b>9</b>	2	B	я	<b>.</b>	3
R <sub>32</sub>	¥	¥	æ	2	9	u .
R <sub>30</sub>	0=0	CH <sub>3</sub> O=O	P. C. P. P. C. P. C. P. P. C. P. P. C. P. P. C. P. C. P.	0,0	0==0	CH <sub>3</sub>
Example	318	319	320	321	322	323

A+1)	6	_	01	302		
MS (M+1)	529	601	572	600, 602	502	536
mp.(°C)						
2	¥	ŧ	3	2	# ·	4
-Ar	8	2	2	27	3	#
×	17	3	æ	=	ä	2
R <sub>32</sub>	11	В	3	3	z	=
R <sub>30</sub>	0H <sub>3</sub>	N CO	0=0	Br S O	0= 5 - 0= 0 - - - - - - - - - - - - - - - - - - -	ο= «= ο
Example	324	325	326	327	328	329

MS (M+1)	564	540	556	540	590	564
mp.(°C)						
Z	g	3	- ·	23	¥	3
-Ar	y	y	3	2	ŧ	y
XX	2	=	æ	מ	3	3
R <sub>32</sub>	n n		H	¥	y.	ij
R <sub>30</sub>	C <sub>3</sub> H <sub>7</sub>	0=0=0	0=0	0= ω=0	0=0	CH, CH S = 0
Example	330	331	332	333	334	335

	4			
MS (M+1)	290	536	540	468
mp.(°C)				
7	y	И	æ	9
-Ar	y	22	=	=
X <sub>2</sub>	11	27	ä	æ
R <sub>32</sub>	3	19	z	HO - CH
R <sub>30</sub>	0=0	£	Z 0=0	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> C(O)-
Example	336	337	338	339

MS (M+1)	496	439	467	523	520	520
mp.(°C)						
2	ä	ä	2	¥	æ	5
-Ar	æ	B	25	מ	±	
X <sub>2</sub>	z	р	ij	4	¥	מ
R <sub>32</sub>	z	~£	IJ	S CH <sub>2</sub>	CH <sub>3</sub>	3
<b>R</b>		CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> C(O)-		OCH3 OH:C,*O	0=0	0=0/
Example	340	341	342	343	344	345

		<del></del>				<del></del>	
MS (M+1)	501	200	757	506	476	520	622
mp.(°C)							
2	æ	3	3	Ξ	37	2	3
-Ar	צ	2	3	2	9	3	7
X <sub>2</sub>	2	2	2	Ħ	а	11	3
R <sub>32</sub>	3	2	2	2	37	5	я
R <sub>30</sub>	0=0, TO	0=0	CH3CH2O-C(O)-	S CH <sub>2</sub>	0=0	0,000	0,000
Example	346	347	348	349	350	351	352

MS (M+1)	502	460	452	531	521	564, 566
mb.(°C)						2
Z	Ħ	3	19	ä	ų	33
-Ar	מ	¥	u	я	я	z
X <sub>2</sub>	1	ä	u	я	3	ij
R <sub>32</sub>	¥	z	31 21	=	3	B
R <sub>30</sub>	0=0	0=s=0	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> C(O)-	0=0	O=O	Br (
Example	353	354	355	356	357	358

3
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19

MS (M+1)	572	567	477	505	555	442
mp.(°C)						
2	19	z	ž	IJ	2	ij
-Ar	±	¥	צ	23	÷	=
×	7	39	y	и	u	2
R <sub>32</sub>	2	я	, ę	*	я	F. () () () () () () () () () () () () ()
<b>R</b> <sub>30</sub>	- 8 - 5	0= S=0	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> CO	0=0	0=0, HOO	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> C(O)-
Example	365	366	367	368	369	370

		<u> </u>			<del></del>	
MS (M+1)	470	520	473	523	445	477
mp.(°C)						
7	3	3	=	<b>a</b> .	2	3
-Ar	п	5	5	3	19	2
X <sub>2</sub>	ij	2	3	3	8	79
R <sub>32</sub>	=	2	S - LOV	ā	77	OH <sub>3</sub> OH <sub>2</sub>
<b>c</b>	0=0	OCH3	O C C TFA salt	DO -	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> C(O)-	
Example	371	372	373	374	375	376

MS (M+1)	520	528	469	479	522
mp.(°C)		,			
Z	B	ä	3	9	ä
-Ar	ש	¥	3	29	3
X <sub>2</sub>	я	æ	¥	¥	я
R <sub>32</sub>	2	=		ш	н
R <sub>30</sub>	0=0	0=0	0=0 0	0 0	0=0
Example	377	378	379	380	381

	<del></del>					
MS (M+1)	530					
mp.(°C)		169-170	115 dec.	145-146	145-146	132
7	2	æ	3	3	2	3
-Ar	æ	7			Z Z	
X X	Ħ	-(CH <sub>2</sub> )2-O-	-CH <sub>2</sub> -O-CH <sub>2</sub> -	-CH <sub>2</sub> -S-CH <sub>2</sub> -	-(CH <sub>2</sub> ) <sub>3</sub> -	2
<b>19</b>	3	CH <sub>2</sub>	3	T T	3	=
$R_{30}$	0=0	OH.C.	B	31	9	¥
Example	382	383	384	385	386	387

MS (M+1)	567	516	577	571
mp.(°C)				
Z	2	#	2	3
-Ar	¥	נו	я	#
χ	-CH <sub>2</sub> -O-CH <sub>2</sub> -	±	z	3
R <sub>32</sub>	HO N	CH <sub>3</sub> O CH <sub>2</sub>	3	3
R <sub>30</sub>	So	£0 0=0	O=0	<u>0</u> 0 = 0
Example	388	389	390	391

		<u> </u>			
MS (M+1)	537	512	525	545	579
mp.(°C)					
Z	11	7	\$	2	2
-Ar	z	z	31	2	¥
××	и	¥	2	=	2
R <sub>32</sub>	ŧ		For No.	¥	æ
$R_{\scriptscriptstyle 30}$	O=0	O=0	£	O=0	<u>0</u> =0
Example	392	393	394	395	966

MS (M+1)	508	544.9	537	490
1				
mp.(°C)				
2	ע	B	¥	39
-Ar	39	14	æ	3
X <sub>2</sub>	n n	2	и	3
R <sub>32</sub>	CH3 CH3 CH3	CH <sub>3</sub> CH <sub>2</sub>	CH <sub>3</sub> O CH <sub>2</sub>	HO L
<b>R</b> 30	S	0=0 0	0=0 0	HO 0=0
Example	397	398	668	400

				<u> </u>	
MS (M+1)	492	547.5	543 (M-1)	582.8	567.2
mp.(°C)					
7	2	3	2	2	ä
-Ar	5	11	37	2	22
ŽX	n	2	2	2	įį
R <sub>32</sub>	CH, CH,	S CH <sub>2</sub>	P. N	2 0 0 \\ \rightarrow \frac{\text{\frac{Q}{2}}{\frac{Q}{2}}}{\frac{Q}{2}}	3
$R_{30}$	0=0 0=0	ij	O=0	5-2 5-2 5-2 5-2	P. O.
Example	401	402	403	404	405

MS (M+1)	553.1	573.9	9.609	540	520.3
mp.(°C)					
2	79	z	*	3	*
-Ar	и	¥	u	¥	2
X <sub>2</sub>	Ŀ	ij	z	H.	22
R <sub>32</sub>	¥	H.	æ	C C C C C C C C C C C C C C C C C C C	IJ
R <sub>30</sub>	£	0=0	0=0 0	O=0	± 0=0
Example	406	407	408	409	410

Γ	<del>- 1-</del>	1			
MS (M+1)		540.1	571	573.9	534
mp.(°C)					
Z		u	3	2	99
-Ar		¥	· <del>'</del>	2	*
χ		¥	3	и	79
<b>B</b>		Ħ	2	2	9
R <sub>30</sub>	7	0=0	S	0=0 O=0	F. F. O=0
Example		11	412		414

		_		
MS (M+1)		590 (M* -1)	553.4	
mp.(°C)	161-162	145-146		126-128
2	ä	ë	æ	2
-Ar	и	2	Ξ	
X <sub>2</sub>	IJ	z	-CH <sub>2</sub> -C(0)-NH-	<b>3</b>
R <sub>32</sub>	PO SHO	æ	Q	T T
<b>R</b>	υ=0	O=0	0=0 0	υ=0 υ=0
Example	415	416	417	418

Example	<b>8</b>	R <sub>32</sub>	X <sub>2</sub>	-Ar	Z	mp.(°C)	MS (M+1)
419	O=0	4	¥		n e	159-162	

The compounds of Examples 302 to 419 are selective inhibitors of cathepsin B, having  $IC_{50}s$  for inhibition of cathepsin B, in the in vitro cathepsin B assay described above, which are typically in the range from about 5 nM to about 1000 nM. Illustrative of the invention, the  $IC_{50}$  in the in vitro cathepsin B assay is about 5 nM for the compound of example 303.

In view of their properties as selective or broad based inhibitors of cathepsin L, S and/or B the Compounds of the Invention described above in Examples 154 to 419 may be used for treatment or prophylaxis of diseases or medical conditions mediated by cathepsin L, S or B; for instance as hereinbefore described.

Example 420 Preparation of 1,000 capsules each containing 25 mg of a Compound of the Invention, using the following ingredients:

Compound of the Invention	25.00 g
Lactose	192.00 g
Modified starch	80.00 g
Magnesium stearate	3.00 g

<u>Procedure</u>: All the powders are passed through a screen with openings of 0.6 mm. Then the drug substance is placed in a suitable mixer and mixed first with the magnesium stearate, then with the lactose and starch until homogeneous. No. 2 hard gelatin capsules are filled with 300 mg of said mixture each, using a capsule filling machine.

### **CLAIMS**

A dipeptide nitrile in which the C-terminal carboxy group of the dipeptide is replaced by a
nitrile group (-C≡N) and in which the N-terminal nitrogen atom is substituted via a peptide or
pseudopeptide linkage which optionally additionally comprises a -methylene-hetero atomlinker or an additional hetero atom, directly by aryl, lower alkyl, lower alkenyl, lower alkynyl
or heterocyclyl,

or a physiologically-acceptable and -cleavable ester or a salt thereof, for use as a pharmaceutical.

2. A compound of formula I, or a physiologically-acceptable and -cleavable ester or a salt thereof

$$R = \begin{bmatrix} 1 \\ 1 \end{bmatrix} X_1 - NH = \begin{bmatrix} R_3 \\ R_2 \end{bmatrix} C - NH = \begin{bmatrix} R_4 \\ R_5 \end{bmatrix}$$

wherein:

R is optionally substituted (aryl, lower alkyl, lower alkenyl, lower alkynyl, or heterocyclyl); R<sub>2</sub> and R<sub>3</sub> are independently hydrogen, or optionally substitued [lower alkyl, cycloalkyl, bicycloalkyl, or (aryl, biaryl, cycloalkyl or bicycloalkyl)-lower alkyl]; or R<sub>2</sub> and R<sub>3</sub> together represent lower alkylene, optionally interrupted by O, S or NR<sub>6</sub>, so as to form a ring with the carbon atom to which they are attached

wherein  $R_6$  is hydrogen, lower alkyl or aryl-lower alkyl; or either  $R_2$  or  $R_3$  are linked by lower alkylene to the adjacent nitrogen to form a ring;  $R_4$  and  $R_5$  are independently H, or optionally substituted (lower alkyl, aryl-lower alkyl), -  $C(O)OR_7$ , or  $-C(O)NR_7R_8$ ,

wherein

 $R_7$  is optionally substituted (lower alkyl, aryl, aryl-lower alkyl, cycloalkyl, bicycloalkyl or heterocyclyl), and

R<sub>8</sub> is H, or optionally substituted (lower alkyl, aryl, aryl-lower alkyl, cycloalkyl, bicycloalkyl or heterocyclyl), or

R<sub>4</sub> and R<sub>5</sub> together represent lower alkylene, optionally interrupted by O, S or NR<sub>6</sub>, so as to form a ring with the carbon atom to which they are attached

wherein R<sub>6</sub> is hydrogen, lower alkyl or aryl-lower alkyl, or

 $R_4$  is H or optionally substituted lower alkyl and  $R_5$  is a substituent of formula  $-X_2-(Y_1)_n-(Ar)_p$ -Q-Z

wherein

 $Y_1$  is O, S, SO, SO<sub>2</sub>,  $N(R_6)SO_2$ ,  $N-R_6$ ,  $SO_2NR_6$ ,  $CONR_6$  or  $NR_6CO$ ;

n is zero or one;

p is zero or one;

 $X_2$  is lower alkylene; or when n is zero,  $X_2$  is also  $C_2$ - $C_7$ -alkylene interrupted by O, S, SO, SO<sub>2</sub>, NR<sub>6</sub>, SO<sub>2</sub>NR<sub>6</sub>, CONR<sub>6</sub> or NR<sub>6</sub>CO;

wherein R<sub>6</sub> is hydrogen, lower alkyl or aryl-lower alkyl;

Ar is arylene;

Z is hydroxy, acyloxy, carboxyl, esterified carboxyl, amidated carboxyl, aminosulfonyl, (lower alkyl or aryl-lower alkyl)aminosulfonyl, or (lower alkyl or aryl-lower alkyl)sulfonylaminocarbonyl; or Z is tetrazolyl, triazolyl or imidazolyl;

Q is a direct bond, lower alkylene,  $Y_1$ -lower alkylene or  $C_2$ - $C_7$ -alkylene interrupted by  $Y_1$ ;

 $X_1$  is -C(O)-, -C(S)-, -S(O)-, -S(O)<sub>2</sub>-, or -P(O)(OR<sub>6</sub>)-,

wherein R<sub>6</sub> is as defined above;

Y is oxygen or sulphur;

L is optionally substituted -Het-, -Het-CH<sub>2</sub>- or -CH<sub>2</sub>-Het-,

wherein Het is a hetero atom selected from O, N or S, and

x is zero or one;

and aryl in the above definitions represents carbocyclic or heterocyclic aryl,

for use as a pharmaceutical;

a pharmaceutical composition comprising a compound of formula I as defined above as an active ingredient;

a method of treating a patient suffering from or susceptible to a disease or medical condition in which a cathepsin is implicated, comprising administering an effective amount of a compound of formula I as defined above to the patient; or

use of a compound of formula I as defined above for the preparation of a medicament for therapeutic or prophylactic treatment of a disease or medical condition in which a cathepsin is implicated.

3. A compound of formula I as defined in claim 2,

provided that when R is lower alkyl not substituted by aryl,

one of  $R_4$  or  $R_5$  is a substituent of formula  $-X_2-(Y_1)_n-(Ar)_n-Q-Z$ ;

provided that when x is one, L is -O-, or -CH<sub>2</sub>-O- and X<sub>1</sub> is -C(O)-,

either one of  $R_4$  or  $R_5$  is a substituent of formula  $-X_2-(Y_1)_n-(Ar)_p-Q-Z$ , or R is not unsubstituted phenyl;

provided that when  $R_2 = R_4 = R_5 = H$ , x is zero and  $X_1$  is -C(O)-,

R<sub>3</sub> is not H, -CH<sub>3</sub>, -CH(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-COOH, or -CH<sub>2</sub>-COO-CH<sub>2</sub>-CH<sub>3</sub>, when R is unsubstituted phenyl,

R<sub>3</sub> is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when R is 4-aminophenyl or 4-nitrophenyl, R<sub>3</sub> is not H when R is 3-aminophenyl, 3-nitrophenyl 2-chloropyridin-4-yl, or vinyl or R<sub>3</sub> is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when R is pyridin-3-yl or 2-chloropyridin-4-yl,

provided that when  $R_2 = R_3 = R_4 = H$ , x is zero and  $X_1$  is -C(O)- and R is phenyl,  $R_5$  is not -CH(CH<sub>3</sub>)<sub>2</sub>,

provided that when  $R_3 = R_4 = H$ ,  $R_5$  is -CH<sub>2</sub>-CH<sub>2</sub>-COOH, x is zero and  $X_1$  is -C(O)-,

 $R_2$  does not form a heterocyclic ring with the adjacent nitrogen atom, and provided that when  $R_2 = R_3 = R_4 = R_5 = H$ , x is zero and  $X_1$  is -SO<sub>2</sub>-,

R is not 4-methylphenyl.

4. A compound according to claim 3, of formula II, or a physiologically-acceptable and -cleavable ester or a salt thereof

$$R_{20} = \begin{bmatrix} L' \\ X_1 \\ X \end{bmatrix} = \begin{bmatrix} R_{23} \\ R_{22} \\ Y \end{bmatrix} = \begin{bmatrix} R_{24} \\ R_{25} \\ R_{25} \end{bmatrix}$$

wherein:

R<sub>20</sub> is optionally substituted (aryl, aryl-lower alkyl, lower alkenyl, lower alkynyl, heterocyclyl, or heterocyclyl-lower alkyl);

R<sub>22</sub> is H, or optionally substitued lower alkyl, and

 $R_{23}$  is optionally substituted (lower alkyl, aryl-lower alkyl, or cyloalkyl-lower alkyl) or  $R_{22}$  and  $R_{23}$  together with the carbon atom to which they are attached form an optionally

substituted (cycloalkyl group or heterocycloalkyl group);

 $R_{24}$  and  $R_{25}$  are independently H, or optionally substituted (lower alkyl, or aryl-lower alkyl), -  $C(O)OR_7$ , or - $C(O)NR_7R_8$ ,

wherein R7 and R8 are as defined above, or

 $R_{24}$  and  $R_{25}$  together with the carbon atom to which they are attached form an optionally substituted (cycloalkyl group or heterocycloalkyl group);

 $X_1$  is as defined in claim 2;

Y is oxygen or sulphur;

L' is optionally substituted (-Het-CH<sub>2</sub>- or -CH<sub>2</sub>-Het-),

wherein Het is a a hetero atom selected from O, N or S, and

x is 1 or 0,

provided that when x is one, L is -CH2-O- and X1 is -C(O)-,

R<sub>20</sub> is not unsubstituted phenyl,

provided that when  $R_{22} = R_{24} = R_{25} = H$ , x is zero and  $X_1$  is -C(O)-,

R<sub>23</sub> is not H, -CH<sub>3</sub>, -CH(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-COOH, or -CH<sub>2</sub>-COO-CH<sub>2</sub>-CH<sub>3</sub>, when R<sub>20</sub> is unsubstituted phenyl,

R<sub>23</sub> is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when R<sub>20</sub> is 4-aminophenyl or 4-nitrophenyl,

 $R_{23}$  is not H when  $R_{20}$  is 3-aminophenyl, 3-nitrophenyl 2-chloropyridin-4-yl, or vinyl, or

R<sub>23</sub> is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when R<sub>20</sub> is pyridin-3-yl or 2-chloropyridin-4-yl,

provided that when  $R_{22} = R_{23} = R_{24} = H$ , x is zero and  $X_1$  is -C(O)- and  $R_{20}$  is phenyl,

 $R_{25}$  is not -CH(CH<sub>3</sub>)<sub>2</sub>,

provided that when  $R_{23} = R_{24} = H$ ,  $R_{25}$  is -CH<sub>2</sub>-CH<sub>2</sub>-COOH, x is zero and  $X_1$  is -C(O)-,

 $R_{22}$  does not form a heterocyclic ring with the adjacent nitrogen atom, and provided that when  $R_{22} = R_{23} = R_{24} = R_{25} = H$ , x is zero and  $X_1$  is -SO<sub>2</sub>-,

R<sub>20</sub> is not 4-methylphenyl.

5. A compound according to claim 3, of formula II' or a physiologically-acceptable and cleavable ester or a salt thereof

$$R_{20} = \begin{bmatrix} L' \\ X_1 \\ X \end{bmatrix} = \begin{bmatrix} R_{23} \\ K \end{bmatrix} = \begin{bmatrix} R_{24} \\ K \end{bmatrix} = \begin{bmatrix} R_{24} \\ K \end{bmatrix} = \begin{bmatrix} R_{24} \\ K \end{bmatrix}$$

wherein:

R<sub>20</sub>' is optionally substituted (C<sub>6</sub>-C<sub>18</sub> aryl or C<sub>4</sub>-C<sub>18</sub> heteroaryl);

R<sub>22</sub>' is H, or optionally substitued C<sub>1</sub>-C<sub>8</sub> alkyl, and

R<sub>23</sub>' is optionally substituted (C<sub>2</sub>-C<sub>8</sub> alkyl, or C<sub>7</sub>-C<sub>14</sub> aralkyl), or

R<sub>22</sub>' and R<sub>23</sub>' together with the carbon atom to which they are attached form an optionally substituted (C<sub>3</sub>-C<sub>8</sub> cycloalkyl group or C<sub>4</sub>-C<sub>7</sub> heterocycloalkyl group);

 $R_{24}$ ' and  $R_{25}$ ' are independently H, or optionally substituted ( $C_1$ - $C_8$  alkyl,  $C_7$ - $C_{14}$  aralkyl, or  $C_5$ - $C_{14}$  heteroaralkyl), -C(O)OR<sub>6</sub>', or -C(O)NR<sub>6</sub>'R<sub>7</sub>',

wherein

 $R_6$ ' is optionally substituted ( $C_1$ - $C_8$  alkyl,  $C_7$ - $C_{14}$  aralkyl,  $C_3$ - $C_8$  cycloalkyl,  $C_4$ - $C_7$  heterocycloalkyl,  $C_5$ - $C_{14}$  heteroaralkyl,  $C_6$ - $C_{14}$  aryl, or  $C_4$ - $C_{14}$  heteroaryl), and  $R_7$ ' is H, or optionally substituted ( $C_1$ - $C_8$  alkyl,  $C_7$ - $C_{14}$  aralkyl,  $C_3$ - $C_8$  cycloalkyl,  $C_4$ - $C_7$  heterocycloalkyl,  $C_5$ - $C_{14}$  heteroaralkyl,  $C_6$ - $C_{14}$  aryl, or  $C_4$ - $C_{14}$  heteroaryl), or

R<sub>24</sub>' and R<sub>25</sub>' together with the carbon atom to which they are attached form an optionally substituted (C<sub>3</sub>-C<sub>8</sub> cycloalkyl group or C<sub>4</sub>-C<sub>7</sub> heterocycloalkyl group);

$$X_1$$
 is -C(O)-, -C(S)-, -S(O)-, -S(O)<sub>2</sub>-, -P(O)(OR<sub>6</sub>')-

wherein R<sub>6</sub>' is as defined above;

Y is oxygen or sulphur;

L' is optionally substituted (-Het-CH<sub>2</sub>- or -CH<sub>2</sub>-Het-),

wherein Het is a a hetero atom selected from O, N or S, and x is 1 or 0,

provided that when x is one, L' is -CH<sub>2</sub>-O- and X<sub>1</sub> is -C(O)-

R<sub>20</sub>' is not unsubstituted phenyl, provided that when  $R_{22}' = R_{24}' = R_{25}' = H$ , x is zero and  $X_1$  is -C(O)-,

R<sub>23</sub>' is not H, -CH<sub>3</sub>, -CH(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-COOH, or -CH<sub>2</sub>-COO-CH<sub>2</sub>-

CH<sub>3</sub>, when R<sub>20</sub>' is unsubstituted phenyl,

R<sub>23</sub>' is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when R<sub>20</sub>' is 4-aminophenyl or 4nitrophenyl,

R<sub>23</sub>' is not H when R<sub>20</sub>' is 3-aminophenyl, 3-nitrophenyl, 2-chloropyridin-4-yl, or vinyl, or

R<sub>23</sub>' is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when R<sub>20</sub>' is pyridin-3-yl or 2-chloropyridin-4-yl, provided that when  $R_{22}' = R_{23}' = R_{24}' = H$ , x is zero and  $X_1$  is -C(O)- and  $R_{20}'$  is phenyl,

 $R_{25}$ ' is not -CH(CH<sub>3</sub>)<sub>2</sub>,

provided that when  $R_{23}$ ' =  $R_{24}$ ' = H,  $R_{25}$ ' is -CH<sub>2</sub>-CH<sub>2</sub>-COOH, x is zero and  $X_1$  is -C(O)-,

R<sub>20</sub>' does not form a heterocyclic ring with the adjacent nitrogen atom, and provided that when  $R_{22}' = R_{23}' = R_{24}' = R_{25}'$  H, x is zero and  $X_1$  is -SO<sub>2</sub>-,

R<sub>20</sub>' is not 4-methylphenyl.

#### A compound of formula III 6.

wherein

R<sub>30</sub> is an acyl group derived from an organic carboxylic, carbonic, carbamic or sulfonic acid; R<sub>32</sub> and R<sub>33</sub> are independently hydrogen, lower alkyl, cycloalkyl, bicycloalkyl, or (aryl, biaryl, cycloalkyl or bicycloalkyl)-lower alkyl; or R<sub>32</sub> and R<sub>33</sub> together represent lower alkylene so as to form a ring together with the carbon to which they are attached;

R<sub>34</sub> is hydrogen or lower alkyl;

X2,Y1, Ar, Q, Z, n and p are as defined in claim 2; and pharmaceutically acceptable salts and esters thereof, for use as a pharmaceutical.

- A compound of formula III as defined in claim 6, wherein R<sub>30</sub> is an acyl group derived from an organic carboxylic, carbamic or sulfonic acid,
   and pharmaceutically acceptable salts and esters thereof.
- 8. A compound according to claim 7, wherein
  - (a) p is one;
  - (b)  $Y_1$  is O, S, SO, SO<sub>2</sub>, N(R<sub>6</sub>)SO<sub>2</sub> or N-R<sub>6</sub>; and
  - (c)  $X_2$  is lower alkylene; or when n is zero,  $X_2$  is also  $C_2$ - $C_7$ -alkylene interrupted by O, S, SO, SO<sub>2</sub> or NR<sub>6</sub>,

and pharmaceutically acceptable salts and esters thereof..

9. A compound according to claim 2, of formula IV

$$R_{40} - C - NH - C - CO - NH - C - C = N$$

$$R_{43} - R_{45}$$

$$R_{45} - C = N$$

$$R_{44} - C = N$$

$$R_{45} - C = N$$

wherein

R<sub>40</sub> is substituted phenyl or heterocyclic aryl, (mono- or di- carbocyclic or heterocyclic aryl)lower alkyl or lower alkenyl, or heterocyclyl;

R<sub>42</sub> is hydrogen or lower alkyl;

R<sub>43</sub> is carbocyclic or heterocyclic aryl - lower alkyl;

R<sub>44</sub> and R<sub>45</sub> are independently hydrogen or lower alkyl; or

R<sub>44</sub> and R<sub>45</sub> combined represent lower alkylene;

and pharmaceutically acceptable salts and esters thereof.

10. A compound according to claim 3 of formula V, V' or V"

$$R_{20} = \begin{bmatrix} L' \\ X_1 \end{bmatrix} X_1 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_1 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_1 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_2 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_1 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_2 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_1 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_2 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_1 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_2 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_1 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_2 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_1 = \begin{bmatrix} R_{23} \\ R_{25} \end{bmatrix} X_2 = \begin{bmatrix} R_{23} \\ R_{$$

$$R_{30}' \cdot NH - \frac{E}{C} - CONH - C - C = N \qquad V'$$

$$R_{40} - C - NH - \frac{E}{C} - CO - NH - C - C = N \qquad V'$$

$$R_{40} - C - NH - \frac{E}{C} - CO - NH - C - C = N \qquad V''$$

wherein the symbols are as defined above, and physiologically-acceptable and -cleavable esters or salts thereof.

- 11. A process for the preparation of a compound of formula I as defined in claim 2, comprising
  - (a) converting an amide of the formula VI

wherein R, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub> and R<sub>5</sub> have meaning as previously defined in claim 2 for the compounds of formula I to a nitrile of formula I; or

(b) condensing a compound of the formula VII

wherein R<sub>4</sub> and R<sub>5</sub> have meaning as defined in claim 1, with an acid of formula VIII

wherein R, R<sub>2</sub> and R<sub>3</sub> have meaning as defined in claim 1; or with a reactive derivative thereof; or

(c) condensing a compound of the formula Ia

wherein R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub> and R<sub>5</sub> have meaning as defined in claim 1 with an acid corresponding to the group R-[L]<sub>x</sub>-X<sub>1</sub>- or with a reactive derivative thereof; and in the above processes, if required, temporarily protecting any interfering reactive groups and then isolating the resulting compound of the invention; and, if desired, converting any resulting compound into another compound of the invention; and/or if desired, converting a resulting compound into a salt or a resulting salt into the free acid or base or into another salt.

12. A method of inhibiting cathepsin activity in a mammal which comprises administering to a mammal in need thereof an effective amount of a compound of formula I as defined in claim 2.

- 13. A method of treating cathepsin dependent conditions in a mammal which comprises administering to a mammal in need thereof an effective amount of a compound of formula I as defined in claim 2.
- 14. A method according to claim 13 of treating inflammation, osteoporosis, rheumatoid arthritis and osteoarthritis.
- 15. A cathepsin inhibiting pharmaceutical composition which comprises a compound of formula I as defined in claim 2 as an active ingredient.

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$$R = \begin{bmatrix} 1 \\ 1 \end{bmatrix}_{X} \begin{bmatrix} 1 \\ 1 \end{bmatrix}_{X} \begin{bmatrix} 1 \\ 1 \end{bmatrix}_{R_{2}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}_{R_{3}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}_{R_{4}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}_{R_{5}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}_{R_{$$

### (57) Abstract

N-terminal substituted dipeptide nitriles as defined are useful as inhibitors of cysteine cathepsins, e.g. cathepsins B, K, L and S, and can be used for the treatment of cysteine cathepsin dependent diseases and conditions, including inflammation, rheumatoid arthritis, osteoarthritis, osteoporosis, tumors (especially tumor invasion and tumor metastasis), coronary disease, atherosclerosis (including atherosclerotic plaque rupture and destabilization). Particular dipeptide nitriles are compounds of formula (I), or physiologically-acceptable and -cleavable esters or salts thereof, wherein: the symbols are as defined. In particular it has been found that by appropriate choice of groups R, R2, R3, R4, R<sub>5</sub>, X<sub>1</sub>, Y and L, the relative selectivity of the compounds as inhibitors of the various cysteine cathepsin types, e.g. cathepsins B, K, L and S, may be altered, e.g. to obtain inhibitors which selectively inhibit a particular cathepsin type or combination of cathepsin types.

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C. DOCUM	ENTS CONSIDERED TO BE RELEVANT						
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	ation) DOCUMENTS CONSIDERED TO BE RELEVANT	
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KHALID, M. ET AL: "N,N'-disubstituted L-isoglutamines as novel cancer chemotherapeutic agents" DRUGS EXP. CLIN. RES. (1987), 13(SUPPL. 1), 57-60 CODEN: DECRDP; ISSN: 0378-6501, 1987, XP002108052 see page 58: compound 2 see page 59; table I	2-4
X	SUZUE, SEIGO ET AL: "Hepatic agents. I. Synthesis of aminoacyl (and hydroxyacyl)aminoacetonitriles" CHEM. PHARM. BULL. (TOKYO) (1968), 16(8), 1417-32 CODEN: CPBTAL,1968, XP002108053 see page 1424; examples 35,36,39-42 see page 1425; examples 47,53	3
X	PICKEN P P ET AL: "Inhibition of bovine cathepsin B by amino acid-derived nitriles" BIOCHEM. SOC. TRANS. (BCSTB5,03005127);1990; VOL.18 (2); PP.316, XP002108054 Queen's Univ. Belfast;Med. Biol. Cent.; Belfast; BT9 7BL; UK (GB) see table 1	2

....ernational application No.

PCT/EP 98/06937

Box i	Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)
<b> </b>	(Containation of item 1 of first sneet)
This Inter	mational Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:
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ه ا	Claims Nos.: because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
. be	claims Nos.: ecause they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).
Box II O	bservations where unity of invention is lacking (Continuation of item 2 of first sheet)
	ational Searching Authority found multiple inventions in this international application, as follows:
1. As sea	all required additional search fees were timely paid by the applicant, this International Search Report covers all archable claims.
2. As of a	all searchable claims could be searched without effort justifying an additional fee. this Authority did not invite payment any additional fee.
3. As cov	only some of the required additional search fees were timely paid by the applicant, this International Search Report ers only those claims for which fees were paid, specifically claims Nos.:
4. No restr	required additional search fees were timely paid by the applicant. Consequently, this International Search Report is ricted to the invention first mentioned in the claims; it is covered by claims Nos.:
Remark on P	The additional search fees were accompanied by the applicant's protest.  No protest accompanied the payment of additional search fees.
POTION	

## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Although claims 12-14 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.

Claims Nos.: 1

Present claim 1 relates to an extremely large number of possible compounds. Support within the meaning of Article 6 PCT and / or disclosure within the meaning of Article 5 PCT is to be found, however, for only a very small proportion of the compounds claimed. In the present case, the claims so lack support, and the application so lacks disclosure, that a meaningful search over the whole of the claimed scope is impossible. Consequently, the search has been carried out for those parts relating to the compound of claim 2.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as IPEA is normally not to carry out a preliminary examination on matter which has not been searched. This the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

Information on patent family members

Int intional Application No PCT/EP 98/06937

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$$R = \begin{bmatrix} L \\ X_1 - NH \end{bmatrix} \begin{bmatrix} R_3 \\ R_2 \end{bmatrix} \begin{pmatrix} R_4 \\ R_6 \end{bmatrix} C \equiv N$$
 (I)

### (57) Abstract

N-terminal substituted dipeptide nitriles as defined are useful as inhibitors of cysteine cathepsins, e.g. cathepsins B, K, L and S, and can be used for the treatment of cysteine cathepsin dependent diseases and conditions, including inflammation, rheumatoid arthritis, osteoarthritis, osteoporosis, tumors (especially tumor invasion and tumor metastasis), coronary disease, atherosclerosis (including atherosclerotic plaque rupture and destabilization). Particular dipeptide nitriles are compounds of formula (I), or physiologically-acceptable and -cleavable esters or salts thereof, wherein: the symbols are as defined. In particular it has been found that by appropriate choice of groups R, R<sub>2</sub>, R<sub>3</sub>, R<sub>4</sub>, R<sub>5</sub>, X<sub>1</sub>, Y and L, the relative selectivity of the compounds as inhibitors of the various cysteine cathepsin types, e.g. cathepsins B, K, L and S, may be altered, e.g. to obtain inhibitors which selectively inhibit a particular cathepsin type or combination of cathepsin types.

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#### **AMENDED CLAIMS**

[received by the International Bureau on 15 September 1999 (15.09.99); original claim 3 amended; remaining claims unchanged (1 page)]

use of a compound of formula I as defined above for the preparation of a medicament for therapeutic or prophylactic treatment of a disease or medical condition in which a cathepsin is implicated.

3. A compound of formula I as defined in claim 2,

provided that when R is lower alkyl not substituted by aryl,

one of R<sub>4</sub> or R<sub>5</sub> is a substituent of formula -X<sub>2</sub>-(Y<sub>1</sub>)<sub>n</sub>-(Ar)<sub>p</sub>-Q-Z;

provided that when x is one, L is -O-, or -CH2-O- and X1 is -C(O)-,

either one of  $R_4$  or  $R_5$  is a substituent of formula  $-X_2-(Y_1)_n-(Ar)_p-Q-Z$ , or R is not unsubstituted phenyl;

provided that when  $R_2 = R_4 = R_5 = H$ , x is zero and  $X_1$  is -C(O)-,

R<sub>3</sub> is not H, -CH<sub>3</sub>, -CH(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, -CH<sub>2</sub>-COOH, or -CH<sub>2</sub>-COO-CH<sub>2</sub>-CH<sub>3</sub>, when R is unsubstituted phenyl,

R<sub>3</sub> is not H, -CH(CH<sub>3</sub>)<sub>2</sub>, or -CH<sub>2</sub>-CH-(CH<sub>3</sub>)<sub>2</sub>, when R is 4-aminophenyl or 4-nitrophenyl, R<sub>3</sub> is not H when R is 3-aminophenyl, 3-nitrophenyl 2-chloropyridin-4-yl, or vinyl,

R<sub>3</sub> is not -CH<sub>2</sub>-CH<sub>2</sub>-S-CH<sub>3</sub> when R is pyridin-3-yl or 2-chloropyridin-4-yl, or

R<sub>3</sub> is not -CH<sub>2</sub>-CH<sub>2</sub>-COOH when R is phenylmethyl,

provided that when  $R_2 = R_3 = R_4 = H$ , x is zero and  $X_1$  is -C(O)- and R is phenyl,

R<sub>5</sub> is not -CH(CH<sub>3</sub>)<sub>2</sub>,

provided that when  $R_3 = R_4 = H$ ,  $R_5$  is -CH<sub>2</sub>-CH<sub>2</sub>-COOH, x is zero and  $X_1$  is -C(O)-,

R<sub>2</sub> does not form a heterocyclic ring with the adjacent nitrogen atom, and

provided that when  $R_2 = R_3 = R_4 = R_5 = H$ , x is zero and  $X_1$  is -SO<sub>2</sub>-,

R is not 4-methylphenyl.

4. A compound according to claim 3, of formula II, or a physiologically-acceptable and -cleavable ester or a salt thereof

$$R_{20} = L' - X_1 - NH + C = N$$

$$X_1 - NH + C = N$$

$$R_{22} = C - N + C = N$$

$$R_{25} = R_{25}$$

wherein:

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